U.S. Fish and Wildlife Service
Kenai National Wildlife Refuge
P.O. Box 2139
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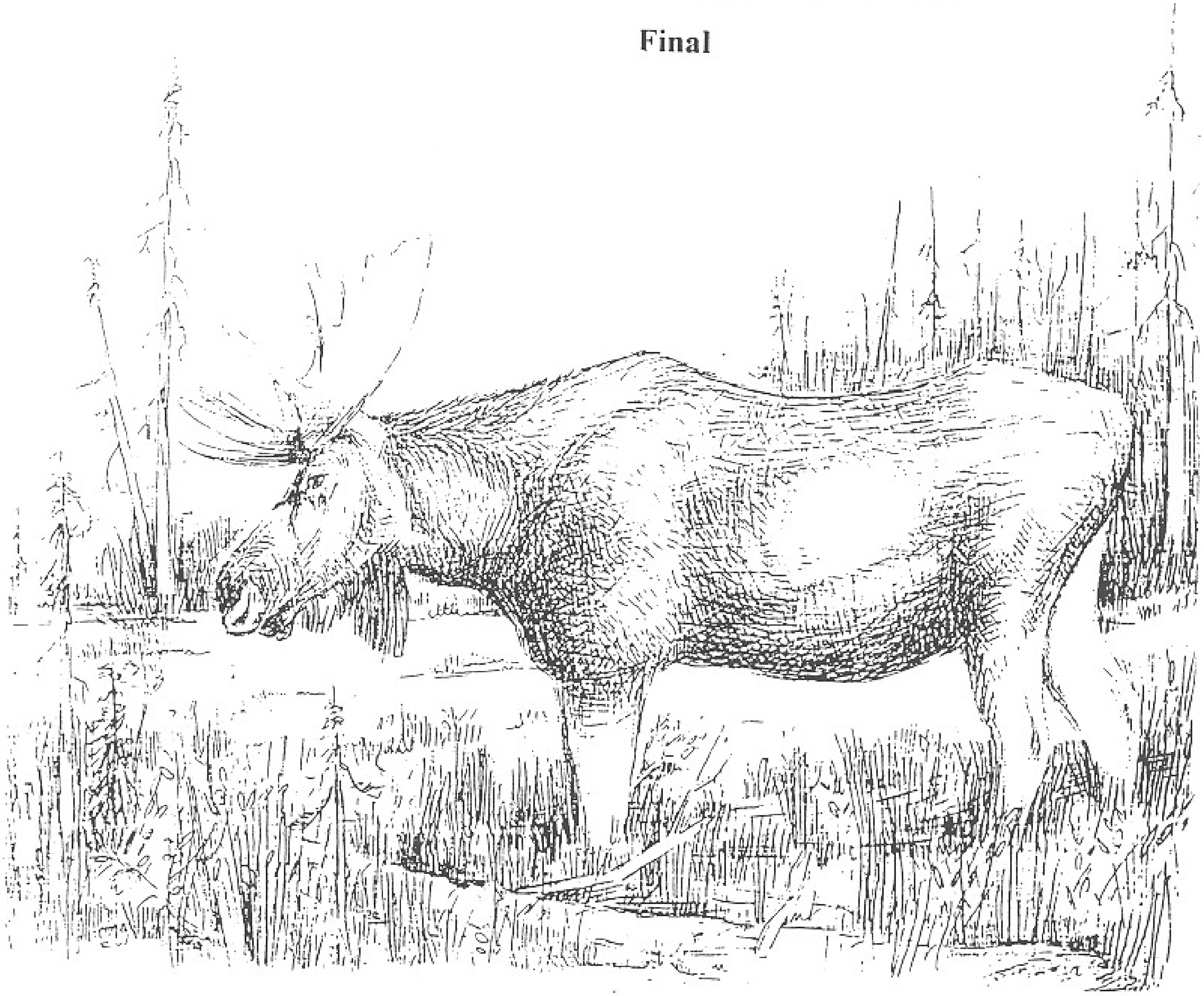
MOOSE/HABITAT MANAGEMENT PLAN

Final



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EXECUTIVE SUMMARY

The 1.97 million acre Kenai National Wildlife Refuge (KNWR) is located on the Kenai Peninsula in southcentral Alaska and is administered by the U.S. Fish and Wildlife Service (Service). Management of moose is one of the most important resource issues on the KNWR, and was in fact the primary purpose for its establishment in 1941 as the Kenai National Moose Range. As the principal ungulate species on the KNWR, moose provide a primary food base for several predator and scavenger species. Viable and healthy moose populations help maintain and enhance biodiversity on the KNWR. In addition, opportunities for consumptive and nonconsumptive uses of moose attract a large number of human visitors to the KNWR annually.

The current estimate of the number of moose in Alaska Game Management Unit 15, most of which lies within the KNWR, is 5,500. Moose populations on the KNWR support an apparently stable population of wolves and are an important food item for black and grizzly bears and for several mammalian and avian species which scavenge predator- or winter-killed moose, including coyotes, lynx, bald eagles, ravens, and wolverines. Recent increasing trends in Alaska's population and visitation to the state can be expected to affect the KNWR through increasing demands on natural resources, and the potential for negative impacts of human activities on wildlife, such as loss and/or fragmentation of habitat. The KNWR will continue to experience the highest level of public use of any national wildlife refuge in Alaska. The Service's mandates for managing wildlife and habitats in their natural diversity while providing opportunities for wildlife-oriented recreation on the KNWR suggests the need for maintaining moose populations on the KNWR at near-current densities, subject to natural fluctuations.

The KNWR Moose/Habitat Management Plan was developed to guide future Service management of moose/habitat on the KNWR. The present status and trend of KNWR moose populations are evaluated, and factors affecting moose population dynamics are examined. Based on these analyses, the Service proposes to work with the Alaska Department of Fish and Game (ADF&G) in the following actions to maintain viable and healthy moose populations at near-current densities on the KNWR: 1) implementation of a long-term habitat manipulation program using prescribed burning as a primary tool; 2) continued monitoring of the status of moose populations using aerial surveys, direct animal assessments, and habitat evaluation; 3) continuation of selective harvest regulations for bull moose and establishment of moose population composition objectives for moose populations in the northern, central, and southern portions of the KNWR; 4) examination of predator-prey relationships and highway accidents involving moose in order to determine their future implications to moose and predator population dynamics and moose management; and 5) identification of research priorities related to moose management on the KNWR.

The Need For Action

Forest succession following human-caused wildfires has been the primary factor affecting moose population dynamics on the Kenai Peninsula during the past century. Early seral forest habitats following fire on the Kenai Peninsula are especially favorable for moose, because they support high densities of important forage species including paper birch, aspen, and willow. Because these species must compete with black and white spruce for canopy dominance in later successional stages, they ultimately grow out of reach for moose and are less dense as understory components. Habitat quality and carrying capacity for moose therefore declines as these seral forest stands mature. Two major wildfires occurred on the northern Kenai Peninsula, in 1947 and 1969, and both resulted in major moose population increases. Significant moose population declines will occur as habitat quality in seral habitats created by these fires declines with forest succession.

The Kenai Peninsula is being affected by an outbreak of spruce bark beetle (*Dendroctonus rufipennis*). The State of Alaska, Division of Forestry, plans for widescale logging on the Peninsula to harvest timber killed by the beetle. Approximately 52,000 acres are to be cut on state land during the next five years. Logging will produce early seral habitats favorable to moose. Extensive logging is also occuring on Cook Inlet Region Incorporated (CIRI) lands on the Kenai Peninsula. Over the past 4 years 10,600 acres have been selectively cut (live and dead spruce) with an additional 19,500 acres to be cut over the next few years (Mike Franger, Land Manager for CIRI, pers. comm.).

Management Recommendations

Habitat Management

Prescribed burning is the most practical, economical, and ecologically sound means to maintain early seral forest stands in the acreages necessary to sustain near-current moose densities on the KNWR and to manage the amount and continuity of forest fuels in order to decrease the risk of large and catastrophic wildfires. Prescribed burning for moose habitat improvement is contingent on fire funding (9120) or refuge operation funding (1261) dedicated to habitat manipulation. This Plan presents three levels of habitat management using prescribed burning: 1) a no action alternative; 2) a minimal action (1-2,000-acres-per-year minimum) alternative; and 3) a moderate action (2,000-4,000-acres-per-year minimum) alternative. The moderate action manipulation level is the Service's preferred alternative. This means that a minimum of 2,000 to 4,000 acres of late-successional habitat will be manipulated per year to an early-successional habitat. The Service recognizes that in some years, conditions may prohibit manipulation, while in other years, the minimum acreage will be exceeded. The Service proposes habitat manipulation objectives for the first three years of this Plan's implementation of 10,369 acres in the Mystery Creek Road area (northern KNWR) and 1,000 acres in the Funny River Road - Slikok Lake area (central KNWR).

The Service recognizes that smoke-related problems (decreased air quality, interference with air and highway traffic) and escaped fires from prescribed burning activities are inherent risks associated with this habitat management tool. The Service will minimize the potential for their occurence through strict adherence to federal and state air quality regulations and Alaska Department of Environmental Conservation permit stipulations, and through active cooperation with the Alaska Division of Forestry, the agency with primary fire suppression responsibilities on the west side of the Kenai Peninsula.

Monitoring the Status of Moose Populations

The Service proposes conducting aerial moose censuses in cooperation with ADF&G at three-year intervals in Game Management Subunit (GMS) 15A, and at five-year intervals in GMS 15B and GMS

15C. Annual moose composition survey techniques which allow estimation of observable moose and of age and sex components will be evaluated and adopted if practical in order to improve the among-year comparability of survey data. Systematic browse utilization surveys will be conducted annually in representative habitats. The Service will continue to support research activities at the ADF&G Moose Research Center as per cooperative agreement.[1] These activities include efforts to assess moose population status using physiological indices of overall health of individual animals and determining genetic variability in Kenai Peninsula moose populations.

Harvest Regulations and Population Composition Objectives

The Service recommends continuation of selective harvest regulations for bull moose on the Kenai Peninsula. Since 1987, bulls legal for harvest must possess either a spike/fork antler configuration on at least one side, have a 50" or greater antler spread, or have at least three brow tines on at least one side.

The Service's mandate for managing for natural diversity of wildlife populations and habitats on the KNWR requires maintaining biologically-sound sex and age structures in moose populations which ensure optimum reproductive performance and maintenance of population quality through genetic variability. Establishment of moose population composition objectives for moose populations on the KNWR is an attempt to do so, while allowing for varying levels and types of public use. These objectives (developed cooperatively with ADF&G) are as follows: 1) northern KNWR (on KNWR portion of GMS 15A) 25-30 bulls:100 cows, (within the Skilak Wildlife Recreation Area) 40 bulls:100 cows; 2) central KNWR (on KNWR portions of GMS 15B-West) 25-30 bulls:100 cows, (on KNWR portions of GMS 15B-East) 40-60 bulls:100 cows; 3) southern KNWR (on KNWR portions of GMS 15C-Caribou Hills) 40-60 bulls:100 cows, (on KNWR portions of GMS 15C-excluding Caribou Hills) 25-30 bulls:100 cows. Current harvest regulations have resulted in gradual increases in overall bull:cow ratios and in prime-age bull:cow ratios on the KNWR. Bubenik (1987) considered 4-8 year olds as prime-age bulls. These animals have a higher reproductive success because of their physical and behavioral superiority (antler development, body size, threat displays, sparring, and fighting).

The refuge recognizes that low bull:cow ratios and severely skewed male age structures due to harvest intensity might not be in the best longterm interest of Kenai Peninsula moose populations. Pregnancy rates have apparently not been impacted by low bull:cow ratios in Alaska (as pointed out in the Technical Supplement and in Schwartz *et al.*, 1992), but there is concern that skewed sex ratios and male age structures heavily favoring the younger age classes might over the longterm negatively impact genetic variability and population viability.

Higher bull:cow ratio objectives for the Tustumena Benchlands and the Caribou Hills recognize the importance of these critical habitats as moose rutting areas where large-antlered bulls have historically

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[1] Support of the Moose Research Center would consist of road maintenance, limited facilities maintenance, access to laboratory space and equipment, and possibly temporary personnel. (from Kenai Refuge Final Comprehensive Conservation Plan, p.129). The supplement to the cooperative agreement, dated 26 February 1968, which addresses the Moose Research Center is outdated. A draft Memorandum of Understanding, dated 13 March 1982, was never signed. The refuge manager has requested direction from the Regional Office on a renewal of the Supplemental Cooperative Agreement.

congregated for the rut, (which is not adequately addressed in the refuge's Comprehensive Conservation Plan). The 40-60 bulls:100 cows ratio provides a benchmark. Should changes in access, visitation rates, harvest strategy, etc., occur which significantly impact moose populations in these habitats, a framework will be in place for these management areas. More effort is needed to gather population and composition data in these areas.

Predator-Prey Relationships and Highway-related Mortality

Recent moose population dynamics in the northern KNWR have shown that a moderate density moose population can increase in a multiple predator-moose system (wolves, black bears, and brown bears) when habitat conditions become favorable. The potential for providing sustained numbers of moose to support healthy predator and scavenger populations and high levels of human use on the KNWR using habitat management is greatest before moose densities decline due to the progressive loss of productive habitats created in the past by wildfires. Recent research indicates that when moose populations decline to low densities as a result of decreasing habitat quality, moose populations may not respond to improved habitat resulting from a wildfire or habitat management due to the potentially controlling effect of predation at low moose densities.

Highway accidents involving moose are an increasingly serious public safety hazard on the Kenai Peninsula and have potential to limit moose population growth. Highway accidents are an important source of mortality for breeding-age cow moose on the Kenai Peninsula. The Service proposes to concentrate wintering moose away from roads and residential areas using habitat management and supports expansion of public awareness campaigns to reduce the incidence of roadkills.

Research/Management Study Priorities

The Service and ADF&G identify the following as priorites for information gathering related to moose and habitat management on the KNWR: 1) prescribed fire research involving site and prescription variables; 2) vegetation studies involving fire frequencies, the effects of browsing by herbivores, relationships of fire to blue joint grass, and effects of spruce bark beetle infestations; 3) a population identity study of moose utilizing early seral habitats on the northern KNWR; and 4) refinement of the ADF&G's computerized population simulation models for KNWR moose populations.

INTRODUCTION

The Kenai National Moose Range (Moose Range) was established by President Franklin D. Roosevelt on December 16, 1941, under Executive Order 8979. Its primary purpose was to protect the "giant Kenai moose" and its habitat. Expanding moose populations following fires between 1871 and 1910 drew attention to the area from sportsmen, market hunters, and early conservationists (Spencer and Hakala 1964). Concern over winter die-offs during the 1920s, believed to be due to deteriorating range conditions and severe winter weather (Walker 1923), resulted in a formal proposal in 1932 by the Alaska Game Commission to create a national moose reserve to protect this valuable resource. Ongoing scientific investigations (Palmer 1938, 1939) ultimately led to the establishment of the Moose Range in 1941 (Spencer and Hakala 1964).

The Alaska National Interests Lands Conservation Act (ANILCA) redesignated the Moose Range as the Kenai National Wildlife Refuge (KNWR) on December 2, 1980. The purposes of the refuge are 1) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, moose, bear, mountain goats, Dall sheep, wolves and other furbearers, salmonids and other fish, waterfowl and other migratory and nonmigratory birds; 2) to fulfill international treaty obligations with respect to fish and wildlife and their habitats; 3) to ensure water quality and quantity; 4) to provide opportunities for research, interpretation, environmental education, and land management training; and 5) to provide, in a manner compatible with these purposes, opportunities for fish and wildlife-oriented recreation.

Moose management remains one of the most important resource issues on the KNWR. Opportunities for consumptive (hunting) and nonconsumptive (viewing, photography) uses of moose attract a large number of visitors annually. As the principal ungulate species on the KNWR, moose provide a food base for several predator and scavenger species. Moose are the primary prey for wolves and an important prey item for black bears (calves) and brown bears. Many smaller mammalian and avian predators and scavengers such as wolverine, coyotes, lynx, bald eagles, ravens, and magpies scavenge winter-killed and predator-killed moose. Recognizing the importance of this resource, the KNWR Comprehensive Conservation Plan (1986) stipulated that a step-down management plan for moose populations on the KNWR would be developed and implemented.

A Master Memorandum of Understanding (1982) between the U.S. Fish and Wildlife Service (Service) and the Alaska Department of Fish and Game (ADF&G) regarding fish and wildlife management in Alaska among other agreements recognizes that ADF&G is the primary agency for managing fish and resident wildlife within the State of Alaska. It also recognizes that the Service will manage habitat on Service lands in Alaska in order to ensure conservation of fish and wildlife populations and their habitats in their natural diversity and that fish and wildlife populations will be managed in their natural diversity on Service lands in Alaska.

This Plan details specific management actions to be undertaken by the Service on the KNWR, including habitat management and cooperation with ADF&G in monitoring the status of moose populations using aerial surveys, habitat evaluation, and direct animal assessments. It outlines area-specific moose population composition objectives (developed in cooperation with ADF&G) for the KNWR. Options for regulating harvest to meet these composition objectives are presented for consideration. It addresses predation and roadkills, two important mortality sources for moose on the

KNWR. The Plan identifies several informational needs and research priorities related to moose management on the KNWR. Lastly, the Plan gives a history of KNWR moose management and discusses the implications of recent moose population dynamics.

A comprehensive review of moose population and habitat data and assessment of factors influencing moose population dynamics on the KNWR since its establishment are presented in the Technical Supplement to the Plan. Moose management objectives and recommended strategies presented in the Plan are based on information summarized in the Technical Supplement. Readers are encouraged to refer to this document as necessary for more detailed information.

The Kenai National Wildlife Refuge

Physical Description

The original KNWR boundaries in 1941 encompassed 2.06 million acres (833,000 ha). Boundary changes in 1964 reduced its size to 1.73 million acres (700,000 ha) by removing areas along the Kenai River, coastal lands between the Kasilof River and Point Possession, and a portion of the Harding Ice Field. ANILCA added nearly 250,000 acres (100,000 ha) to the KNWR and designated 1.35 million acres (550,000 ha) as wilderness. With the addition of these lands, the current boundaries encompass 1.97 million acres (797,000 ha) (Figure 1). The KNWR is the single largest federal land management unit on the Kenai Peninsula.

Three major landforms are present on the KNWR: the Kenai Mountains, the Tustumena Benchlands, and the Kenai Lowlands. The eastern portion of the KNWR lies within the Kenai Mountains, which range in elevation from 3,000 to 6,600 feet (900-2000 m). The Tustumena Benchlands, located between Skilak and Tustumena lakes, is a 270 mi^2 (700 km^2) plateau ranging from 800 to 2300 feet (250-700 m) in elevation in the east-central portion of the KNWR. The Kenai Lowlands comprise the western two-thirds of the KNWR. These lowlands consist of ground moraine and stagnant ice terrain with low ridges, hills, and muskeg. Relief ranges from 50 to 250 feet (15-76 m) and the area contains thousands of lakes and ponds.

Vegetation

Habitats on the Kenai Lowlands are predominantly forested with a mixture of white spruce (*Picea glauca*), black spruce (*P. mariana*), quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*). White spruce is the climax species on well-drained soil and black spruce dominates on poorly-drained sites. Approximately half of the forested areas on the Kenai Lowlands are in various successional stages due to fire. Two large human-caused wildfires, in 1947 and 1969, have occurred since the KNWR's establishment. The 1947 burn encompasses 483 mi^2 (1250 km^2), and the 1969 burn encompasses 136 mi^2 (352 km^2) (Figure 2). The major woody vegetation in these burned areas varies considerably with white and black spruce, paper birch, quaking aspen, and several species of willow (*Salix* spp.).

Habitats in the Tustumena Benchlands are characterized by a white spruce dominated forest grading into a subalpine shrub community at higher elevations. Paper birch and quaking aspen are interspersed in various densities throughout the spruce forest, and black cottonwood (*Populus*

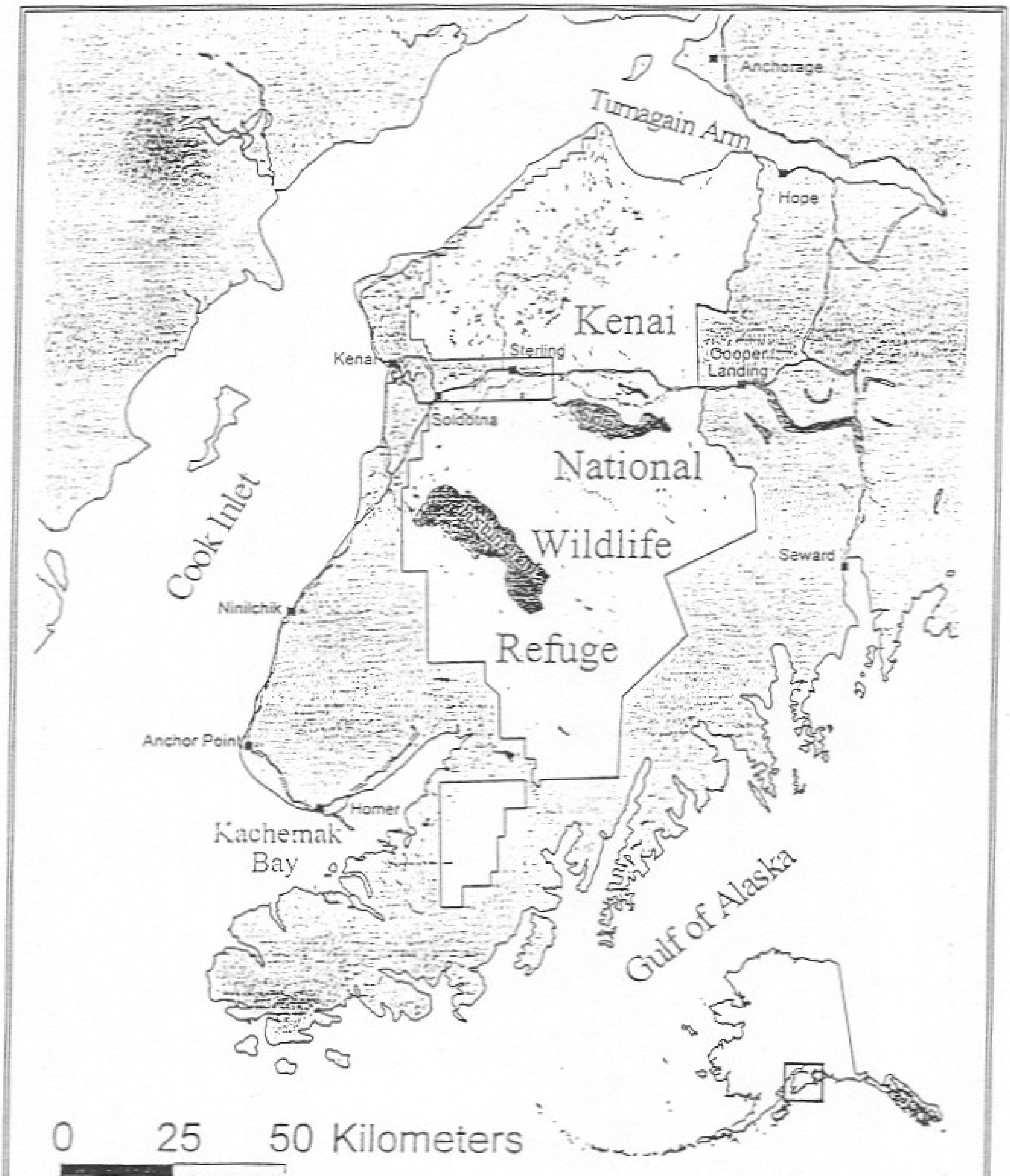

Figure 1. Location of the Kenai National Wildlife Refuge, Kenai Peninsula, Alaska.

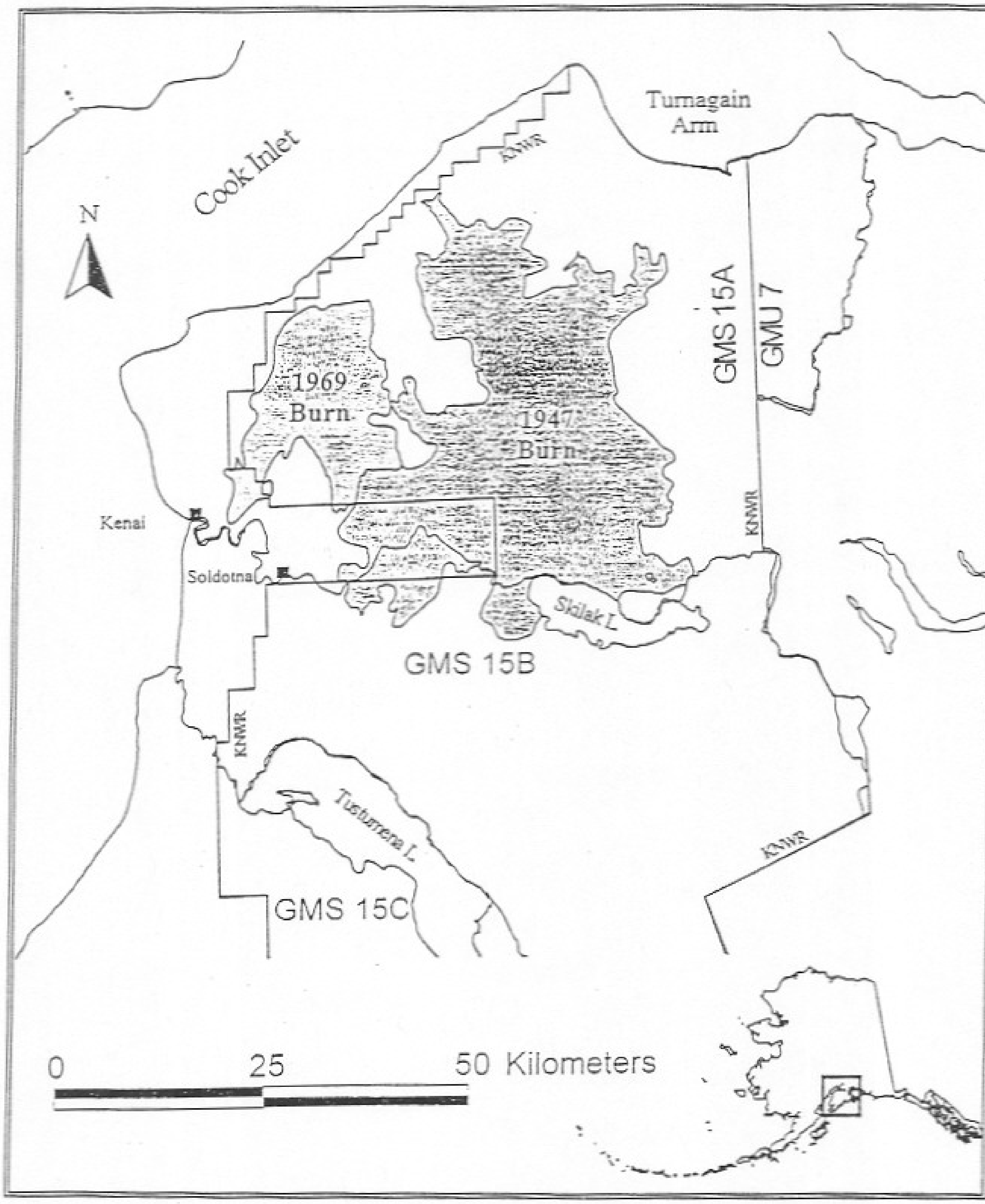

Figure 2. Location of the 1947 and 1969 burns on the Kenai Lowlands, Kenai Peninsula, Alaska.

trichocarpa) is found along streams and rivers. Willow and Sitka alder (*Alnus sinuata*) predominate in the shrub community.

Forests in the Kenai Mountains are dominated in inland areas by white spruce and in coastal areas by Sitka spruce (*P. sitchensis*). Mountain hemlock (*Tsuga canadensis*) and western hemlock (*T. heterophylla*) also occur in foothills. The spruce-birch complex tends to dominate at lower elevations while the spruce-hemlock type is more common above 650 feet (200 m). Pure hemlock stands are also found. Alpine tundra is comprised of tall shrub (willow and alder) and dwarf shrub-lichen communities.

Relationship of the KNWR with Alaska Game Management Units

The Kenai Peninsula contains two State of Alaska Game Management Units (GMU). GMU 7 and GMU 15 cover the eastern and western portions of the Peninsula, respectively (Figure 3). GMU 7 is bounded on the west by the Kenai Mountains and extends eastward to the Gulf of Alaska and Sargent Icefield. GMU 15 is subdivided into Game Management Subunits (GMS) 15A, 15B, and 15C. GMS 15A is bounded on the south by the Kenai River, on the north and west by Cook Inlet, and on the east by the Kenai Mountains. GMS 15B lies between the Kenai River and Skilak Lake to the north and the Kasilof River and Tustumena Lake to the south. It is bounded by Cook Inlet in the west and the KNWR boundary in the east. GMS 15B has been further divided for moose management purposes into GMS 15B-West and GMS 15B-East. Most of GMS 15A and GMS 15B lie within the boundaries of the KNWR, as do the northern portion of GMS 15C and a small area in the northwestern corner of GMU 7.

Although some interchange occurs between moose populations within various GMUs and GMSs on the Kenai Peninsula, they contain more or less discrete moose populations. Their boundaries are therefore less artificial for moose management purposes than those of the KNWR. GMUs and GMSs on the Kenai Peninsula have historically been used as survey areas for fall population composition surveys and, beginning in 1987, as survey areas for density surveys which generate moose population estimates. For these reasons, the area-specific moose management objectives and strategies presented in this Plan utilize portions of the KNWR within GMS's 15A, 15B, and 15C to define management zones for moose.

FUTURE MOOSE MANAGEMENT ON THE KNWR

Moose Management Objectives

Moose populations on the Kenai Peninsula north of Tustumena Lake have responded in dramatic fashion to the conversion of climax forest types (primarily white and black spruce forests in the Kenai Lowlands) to early seral forests (aspen and birch) by fire and other perturbations which have occurred since the late 19th century (Lutz 1960, Spencer and Hakala 1964, Bishop and Rausch 1974,

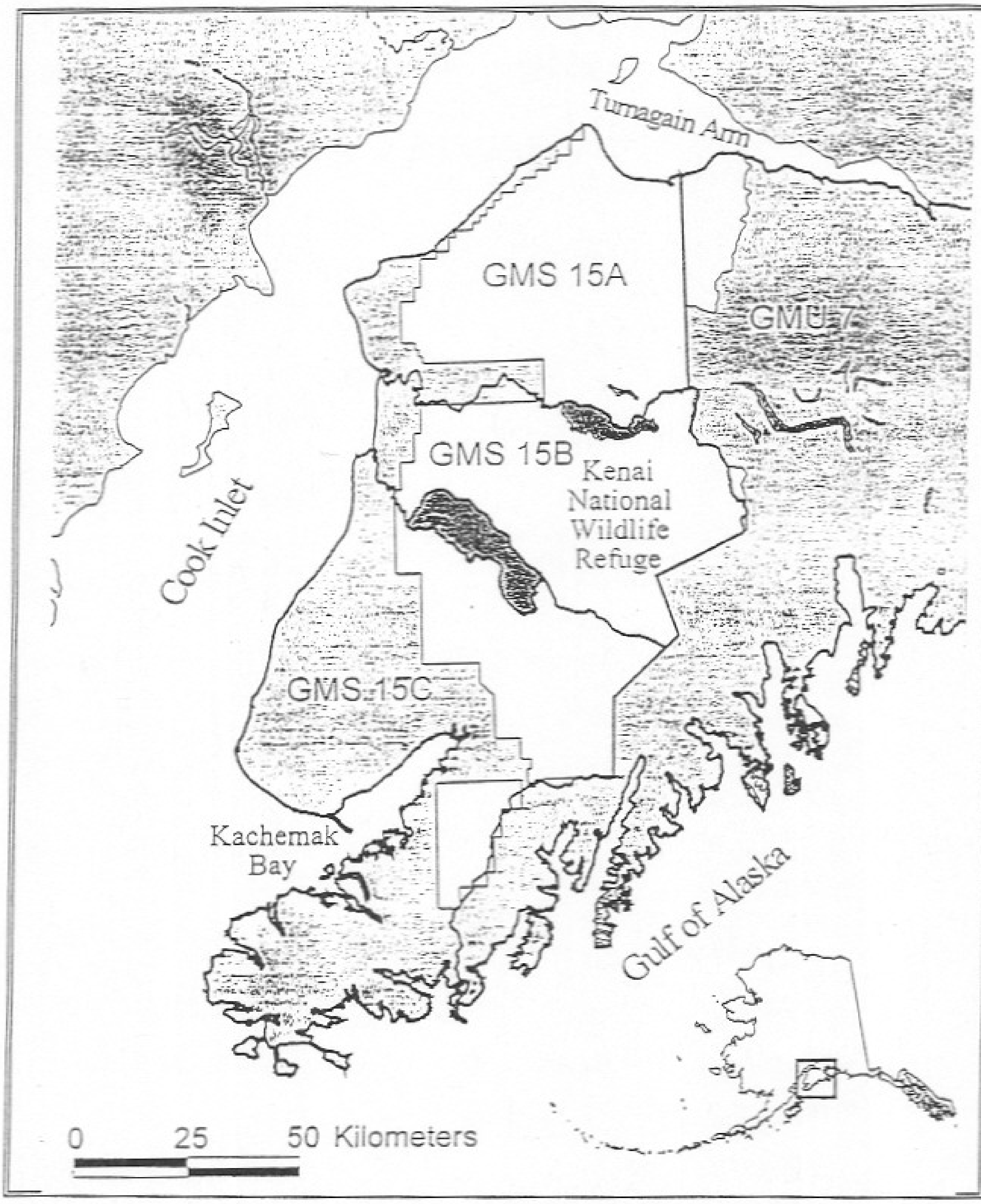

Figure 3. Location of Alaska Game Management Units and Subunits in relation to the Kenai National Wildlife Refuge.

Bailey 1978, Bangs and Bailey 1980). Plant species in these early successional habitats include the principal browse species for moose on the KNWR: paper birch, quaking aspen, and several species of willow.

The KNWR Comprehensive Conservation Plan sets a numerical population objective of 5,500 moose for the KNWR. Of this total, the objective for GMS 15A is 3,600 moose. The uncertainties associated with the future creation and maintenance of new early seral habitats (either by unplanned wildfires or planned habitat management) limit the usefulness of establishing numerical objectives for various moose populations on the KNWR. This is especially true for the GMS 15A moose population which is subject to the loss of prime habitat as the 1969 burn matures. The moose management objectives presented in this Plan therefore do not include numerical population objectives. Rather, they include projections of GMS 15A moose populations under three potential habitat management scenarios: no management, minimal management (1-2,000-acres-per-year managed), and moderate management (2-4,000-acres-per-year managed). These objectives are discussed below.

Within the context of the purposes for the KNWR's establishment and in cooperation with ADF&G, the primary moose management objectives on the KNWR involve maintaining moose densities consistent with 1) providing a prey/food base capable of supporting viable and healthy predator and scavenger populations, thus maintaining natural diversity of wildlife; 2) preventing chronic over-utilization of forage plant species which could result in long-term negative impacts on habitat diversity and quality; 3) providing opportunities for scientific study; and 4) providing opportunities for wildlife-oriented recreation, including consumptive and nonconsumptive uses.

Meeting these moose management objectives will require 1) maintaining an adequate habitat base such that moose populations remain on a high nutritional plane and food resources are not limiting population growth; 2) maintaining biologically-sound sex and age structures which ensure maximum reproductive performance and maintenance of population quality through genetic variability; and 3) careful monitoring of moose population status. The following are therefore prerequisite to meeting these moose management objectives on the KNWR and represent the goals of this Plan:

1) development of a long-term habitat management program for the KNWR, primarily using prescribed fire, which defines area-specific objectives for locations and total acreage of habitat to be manipulated.
2) development of a standardized and systematic moose population assessment program for the KNWR which includes three components: a) aerial surveys to gather population statistics; b) habitat evaluation; and c) direct animal assessments.
3) identification of area-specific population composition (sex and age structure) objectives for moose populations throughout the KNWR, and recommendation of harvest strategies to help meet these objectives.
4) discussion of predation and roadkills in relation to moose population dynamics.
5) identification of informational needs and research priorities related to moose management on the KNWR.

Nonconsumptive use of moose, including viewing and photography, must be accommodated on the KNWR. Wildlife viewing will continue to be a major emphasis of management in the Skilak Lake Wildlife Recreation Area (SLWRA). Opportunities for recreational uses of moose will continue to emphasize the wilderness character of designated Wilderness areas on the KNWR.

Moose Management Recommendations

Habitat Management

Purpose and Objectives

This portion of the Plan describes a program of vegetation management which, if successfully implemented, will increase the long-term minimum amount of early seral forest habitat on the KNWR, while decreasing the risk of major wildfires by reducing the amount and continuity of forest fuels. Specific objectives of the Habitat Management section are as follows:

1. Describe the current forest habitat mosaic on the Kenai Lowlands.
2. Establish the quantity and location of KNWR lands available for forest habitat manipulation.
3. Use a computer model to predict the long-term effects of different levels of annual vegetation manipulation on the abundance of early seral forest habitat, and on moose populations. Select a preferred alternative.
4. Establish a procedure to prioritize KNWR lands for habitat management.
5. Describe specific project areas for the first five years of Plan implementation.
6. Discuss other needs of the habitat management program for evaluation and planning.
7. Evaluate and select techniques available for manipulation of habitat.
8. Outline a five-year work plan with personnel, equipment, and fiscal requirements to meet habitat management objectives, based on the preferred alternative.

Description of Current Forest Habitat Mosaic

In much of interior Alaska, extensive glacial and riparian seral communities, constantly renewed by erosion, flooding, and scouring by ice, provide a relatively stable early seral forest habitat for wintering moose (LeResche *et al.* 1974). Wildfires supplement this permanent base with transient local expansions of early seral habitat, resulting in moose populations which often fluctuate widely but remain generally above those supported by the glacial and riparian base. The Kenai Lowlands, in contrast, have a very limited stable habitat base, consisting of a few narrow stream corridors and glacial outwash plains. Therefore, while the Kenai Lowlands have the potential for providing excellent moose habitat, the carrying capacity in the absence of fire and other large-scale disturbances is quite low. History supports this theory (Spencer and Hakala 1964). In recent years, residential and commercial development along the road system has provided additional disturbed habitat attractive to wintering moose, but has also resulted in high mortality rates due primarily to moose/vehicle interactions (DelFrate and Spraker, 1991).

Figure 4 and Table 1 map and describe all major seral forest habitats resulting from wildfires and other habitat disturbances from the 1947 Skilak Lake fire until 1995. Winter browse available for moose in the 1947 burn has declined almost to the level of the surrounding mature forest. These data indicate that as the 1969 Swanson River fire loses its productive capacity for moose over the next several years, significantly less early seral forest habitat will be present. The Kenai Lowlands are apparently on the brink of a substantial decline in optimal moose wintering habitat.

The future of forest fuel accumulation and resulting increase in the danger of a large and costly wildfire is predictable. In recent years the 1947 and 1969 burns, by virtue of their location and immense size, have provided the northern Kenai Lowlands with a significant measure of protection

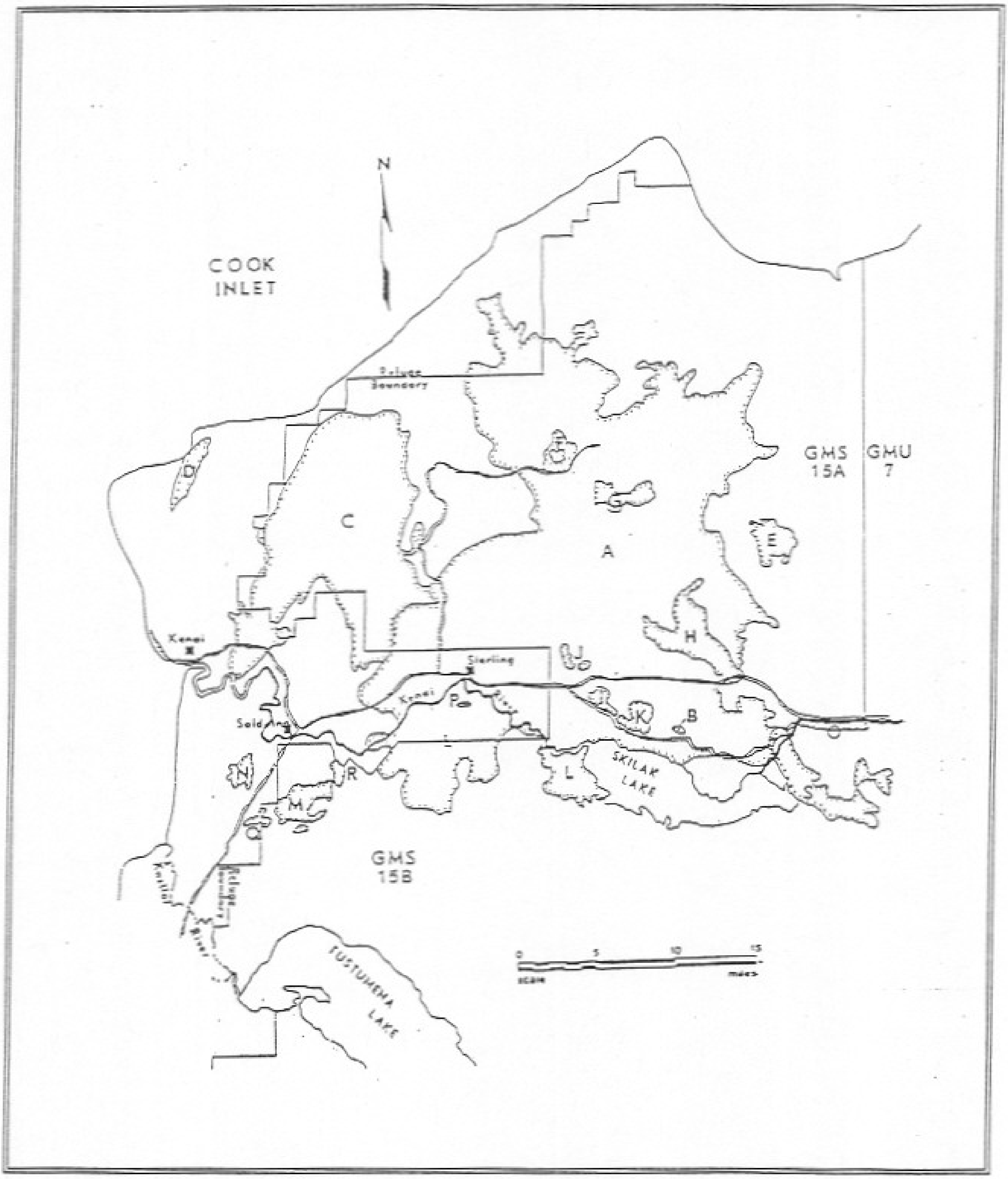

Figure 4. Major upland habitat disturbances from 1947 to 1991 on the northwestern Kenai Peninsula. Letter labels of habitat disturbances refer to Table 1.

Table 1. Major forest habitat disturbances on the Kenai Lowlands in GMS 15A and GMS 15B, 1947 to 1995. Letters in column 1 refer to Figure 4.

Map Reference	Year	Type of disturbance	Area (acres)
GMS 15A[a] (Total area 807,000 acres)			
A	1947	Wildfire	279,400
B	1963	Wildfire	400
C	1969	Wildfire	86,800
D	1970	Wildfire	2,100
E	1974	Wildfire	4,000
F	1975	Mech. crushing	1,100
G	1976	Mech. crushing	1,300
H	1978	Mech. crushing	4,300
I	1984	Crushing[b] & prescr. burning	1,200
J	1986	Crushing[b] & prescr. burning	700
K	1987	Crushing[b] & prescr. burning	1,700
S	1991	Wildfire	700
GMS 15B[a] (Total area 401,000 acres)			
L	1947	Wildfire	30,600
M	1968	Mech. crushing	3,700
N	1969	Wildfire	1,200
O	1969	Wildfire	2,000
P	1979	Wildfire	100
Q	1981	Wildfire	300
R	1988	Firewood harvest & prescr. burning	700
S	1991	Wildfire	7,200

[a] Includes all lands, on and off refuge, in the respective GMSs, above tidal flats and below timberline, as depicted on USGS 1:63,360 series topographic maps.
[b] Crushing done by Alaska Department of Fish and Game after 1983.

against large destructive wildfires. As these burns mature, however, the organic accumulation will increase the fire potential, until the fuel load is again reduced by catastrophic wildfire. The 1947 burn is presently at the stage where its fuel complex will sustain a prescribed fire, but wildfire control is not yet a problem except under the most extreme conditions of drought and high winds. The next few years will provide an opportunity for using prescribed fire to interrupt the fuel continuity of the maturing 1947 burn and adjacent mature fuel complexes to ensure that wildfires continue to be manageable on the northern Kenai Lowlands.

Lands Available for Manipulation

The KNWR Comprehensive Conservation Plan established five management categories on the KNWR: Intensive, Moderate, Traditional, Minimal, and Wilderness. This document specifies that intentional habitat manipulation is allowable on those lands designated as Intensive, Moderate, and

Traditional, except for prescribed burning "for the protection of life or property or significant resource values" within Wilderness or Minimal management categories. The Fish and Wildlife Service Manual (621 FW 3.2A) states that prescribed fire may be used in wilderness areas and proposed wilderness areas in accordance with the following guidelines:

> "When consistent with refuge objectives and contingent upon the existence of a current, approved fire management plan for the wilderness area, prescribed burning is permitted. Burning may even be desirable within wilderness, especially when fire is a natural force that has historically affected the area or when fire is necessary to restore, maintain, protect, or preserve wilderness resources and values of the area, or when controlled burning can reduce fire hazards to the refuge or wilderness. Using mechanically-created firebreaks and motorized equipment for prescribed burning is generally not permitted in a wilderness area. However, firebreaks may be constructed contiguous to the wilderness area."(6 RM 8.8D)

While there seems to be some discretionary latitude for intentional burning in designated Wilderness on the KNWR, this is clearly a matter requiring public review of specific proposals. This plan keeps open the option of prescribed burning in Wilderness and Minimal management categories, however, habitat manipulation in those areas is not a priority and will not be addressed in the following analysis.

Of the other three land management categories, "Intensive" is reserved mainly for road corridors, research and recreational facilities, and commercial operations such as oil and gas fields. While this category may contribute a few peripheral acres for habitat manipulation, it will not be considered in the following analysis. Of the two remaining land management categories, prescribed burning and mechanical techniques may be used in "Moderate" areas, while in areas classified as "Traditional", only prescribed fire may be used. The distribution of these two land management categories on the KNWR is illustrated in Figure 5.

Lands identified in the Comprehensive Conservation Plan as 22(g) that have either been since conveyed to Native corporations or are of undetermined long-term status have been excluded from consideration in this Plan. In order to be consistent with other aspects of moose management, portions of the KNWR within each GMS 15A, GMS 15B, and GMS 15C will be considered individually.

To determine acreages of land potentially productive as moose habitat that were available in the Traditional and Moderate management categories, vegetation type maps were overlaid with land management category boundaries. For each vegetation type polygon, acreages were calculated, totalled, and tabulated. The types were then lumped into "potentially productive" and "unproductive" moose habitat categories. The "unproductive" category includes water bodies and muskeg, while "potentially productive" lands include all upland categories, which consist mainly of forest types.

Table 2 lists the "potentially productive," "unproductive," and total acreage for each land management category in each GMS. The significance of these figures can be illustrated by considering stand rotation (average time between repeat disturbance treatments). It was assumed that manipulation of 100 percent of the potentially productive land is impractical due to various environmental (natural fuel breaks, fuel continuity, etc.), logistic, and safety factors. For analysis, 70

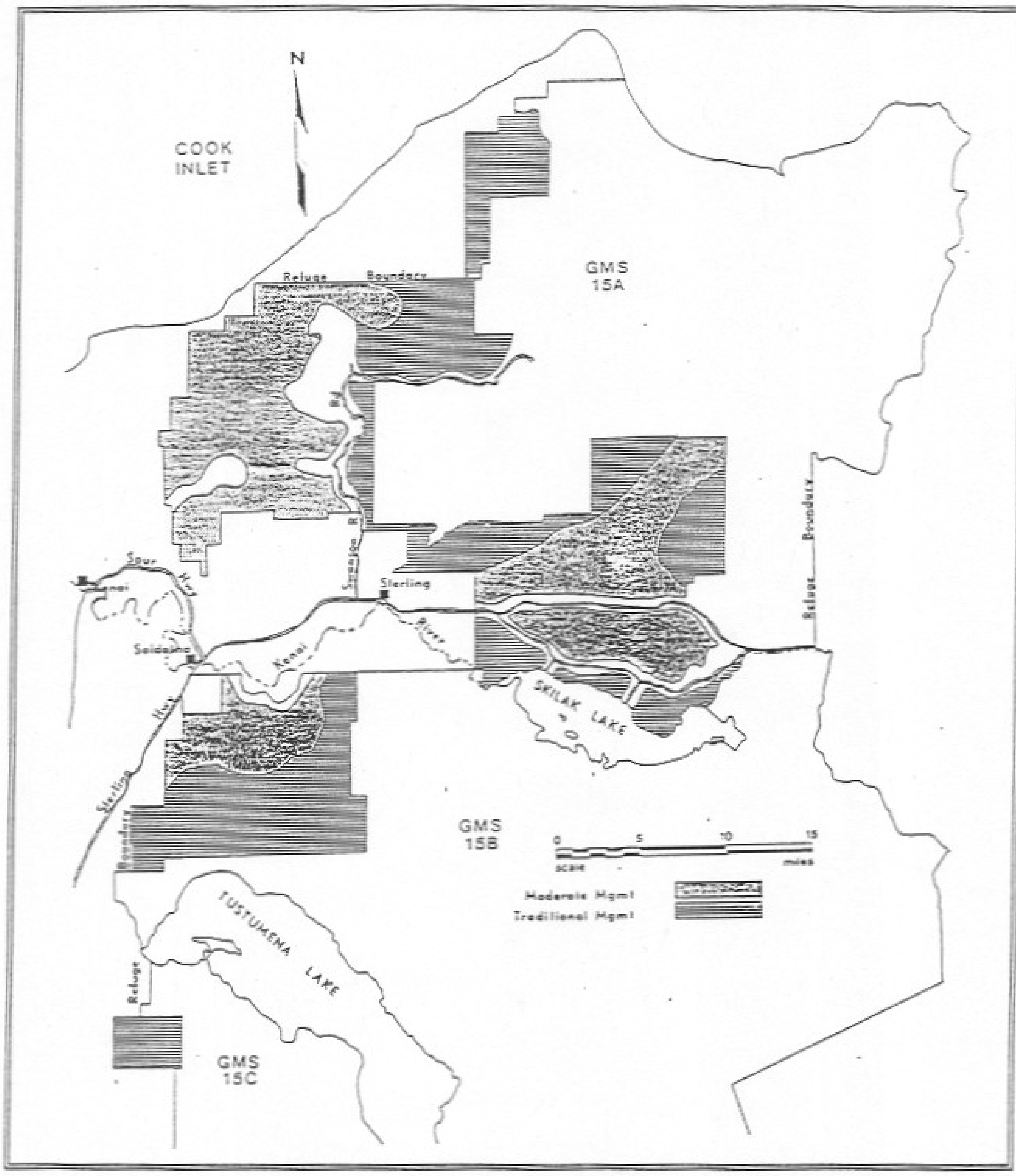

Figure 5. Lands designated for habitat manipulation on the Kenai National Wildlife Refuge, according to the Comprehensive Conservation Plan.

percent manipulation is used. Table 3 presents the total productive acreage for each GMS with average per year treatments for 25-year, 50-year, and 75-year rotations. An important consideration is that the two assumptions, 70 percent manipulation of productive habitats and 50-year rotation period, are best guesses. Some prescribed burns will go beyond 70 percent and others will be less. Finding an average figure for future analysis will require examination of many prescribed burns. The 50-year rotation is also subject to change. Some areas may be repeated in a shorter time while others may require many more years before enough fuels accumulate to support follow-up treatments. The Service will need to evaluate treated areas within 25 to 60 years postburn to determine fuel accumulation and continuity for reburning.

Table 2. Potential productive and non-productive acres (thousands) in Moderate and Traditional management categories, Kenai National Wildlife Refuge, 1996.

Management Category	Productive	Non-productive	Totals
GMS 15A			
Moderate	101.3	29.4	130.7
Traditional	83.9	15.4	99.3
Total	185.2	44.9	230.1
GMS 15B			
Moderate	19.6	4.0	23.6
Traditional	50.1	11.0	61.1
Total	69.7	15.0	84.7
GMS 15C			
Traditional	11.3	1.3	12.6

These rotation periods may be put into perspective by noting that nearly 50 years may be required to accumulate enough fuels for a satisfactory prescribed burn on the Kenai Lowlands. Ninety to 100 years may be required for paper birch and aspen to reach harvestable size for timber or firewood. For white spruce, a rotation period of 120 years (Five Year Schedule of Timber Sales for the Kenai-Kodiak Area, July 1994) is adequate for pulpwood and 180 years may yield quality sawlogs (unpublished Timber Management Plan, KNWR files).

Table 3. Potential productive acres (thousands) to be manipulated to achieve an average stand rotation of 25, 50, and 75 years, based on an average of 70 per cent usability of potential productive land, Kenai National Wildlife Refuge, 1996.

Game Mgmt. Unit	70 per cent productive area	25 year rotation	50 year rotation	75 year rotation
15A	129.6	5.9	2.6	1.7
15B	48.8	2.0	1.0	0.7
15C	7.9	0.3	0.1	0.1

With the 70 percent assumption, GMS 15A has adequate lands in appropriate land management categories to indefinitely sustain an annual treatment of 2,600 acres at the rotation period of 50 years and only 1,700 acres per year at a 75-year rotation period. Equivalent estimates available for manipulation in GMS 15B are 1,000 acres per year for a 50-year rotation period, and 700 acres per year for a 75-year period. These annual treatments are the maximum manipulation level of seral habitat per year under the management guidelines established by the Comprehensive Conservation Plan, and the 70 per cent productive assumption.

Productive years for manipulated habitat is dependent on type of habitat manipulated and the density of moose it supports. If densities are low, manipulated areas may not be productive past 15-20 years because browse species will grow out of reach. However, nutritive value of browse, especially birch, that is kept within reach by higher densities of moose may decrease as a result of high utilization rates by moose. The true "productive life" of manipulated habitats at varying rates of utilization by moose is unknown.

Evaluation of the alternatives for habitat management on the KNWR must include assessing such qualitative factors as accessibility of moose to the consumptive and nonconsumptive recreationist. Moose concentrate in the 1969 burn or recently manipulated areas due to habitat quality and are more visible there due to the abundant cover openings. Under the no action habitat manipulation alternative, fewer moose will be more widely distributed and less visible as the forest matures.

The increasing incidence of highway accidents involving moose on the Kenai Peninsula is also apparently a habitat-related phenomenon. Providing good quality wintering habitat outside of developed/residential areas on the Kenai Lowlands may be the best means available to address the moose roadkill problem.

Prioritization of Lands for Manipulation

Several factors were considered when setting the priorities for treating KNWR lands. These include, but are not limited to 1) location of potentially dangerous forest fuels; 2) changing fuel conditions in project areas over time; 3) project cost estimates and availability of funds; 4) existing habitat mosaic, wintering moose distribution, and hunting pressure distribution; and 5) potential conflicts with uses of adjacent KNWR or private lands.

These and other factors will be reviewed annually by the KNWR, the ADF&G, and the Alaska Division of Forestry to select specific lands for habitat manipulation. There also may be instances where "minimum impact" treatments would be justified in "Minimal" and "Wilderness" management categories in the interest of public safety or to prevent serious habitat degradation.

Five-year Habitat Manipulation Objectives for Preferred Alternative

Experience with prescribed burning and other habitat management techniques on the KNWR suggest that it will be very difficult to meet acreage objectives every year, even if adequate funding is available. Uncooperative weather, manpower shortages, burning restrictions, and conflicts with statewide or nationwide fire suppression activities have resulted in uncompleted prescribed burns in three of the last seven years. A five-year acreage objective is therefore recommended, with large annual projects to compensate for years when weather or other factors prevent reaching an annual objective.

Game Management Subunit 15A For the first three to five years of Plan implementation, a 10,369-acre area in the Mystery Creek Road vicinity (Figure 6) will be manipulated. Approximately 40 percent of this area should be left untreated as scattered islands for wildlife cover and seed source for revegetation (Oldemeyer and Regelin 1984). It may be possible to accomplish this with as few as two favorable years out of the five.

The Mystery Creek Road area is recommended for the first three to five years of habitat manipulation for the following reasons:

1) Work in the Mystery Creek Road area would in effect add to the 3,600 acres recently manipulated immediately south in the Skilak Loop vicinity and to the 4,300 acres crushed in that area from 1976 to 1978 (Figure 4), creating a manipulated habitat totalling over 18,000 acres in that portion of the 1947 burn. Manipulation of large acreages is preferable because moose are attracted to areas with abundant forage and can easily damage regrowth vegetation on smaller areas by overbrowsing. Recommended minimum project sizes range from 4942 acres (Oldemeyer and Regelin 1984) to 23,000 acres (Peek *et al.* 1976).

2) The project would result in a fuel break between extensive spruce beetle-killed white spruce stands in the Mystery Hills and the Sterling community.

3) Assuming the use of prescribed fire as the primary management tool, this area is remote enough from Peninsula communities to provide a good margin of safety during these early years of technique development, and smoke management concerns should be less than in most other possible locations.

Game Management Subunit 15B For GMS 15B, the Service proposes an initial average annual objective of 200 acres, totalling 1,000 acres for the first five years. This objective may be increased to 300-400 acres per year during the next five-year period as proficiency with prescribed burning techniques is gained. The treatment areas for the first five years will be selected from the area presented in Figure 7. This area currently contains approximately 300 acres of slash residue from public firewood harvest which should be treated to reduce fire hazard and contains other wooded acreage to be evaluated for treatment. Annual acreages to be manipulated in GMS 15B will necessarily be much smaller than those in GMS 15A due to the necessity of minimizing smoke impacts to the nearby communities of Soldotna, Kenai, and Kasilof.

Game Management Subunit 15C No habitat work is planned for GMS 15C at this time due to the remoteness and small size of the single block of manipulable land (Figure 5).

Other Needs for Evaluation and Planning

Habitat mapping The KNWR currently has timber type maps developed during the late 1950s and the late 1970s which are incomplete, inaccurate, and incompatible with our current information needs. In order to accurately model the effects of habitat manipulation on moose and other wildlife populations on the KNWR, a Geographic Information System database is needed and should include the following layers of information: 1) existing vegetation communities; 2) soil types; 3) physiography (slope, aspect, elevation); 4) climate; 5) wetlands; 6) cultural features (roads,

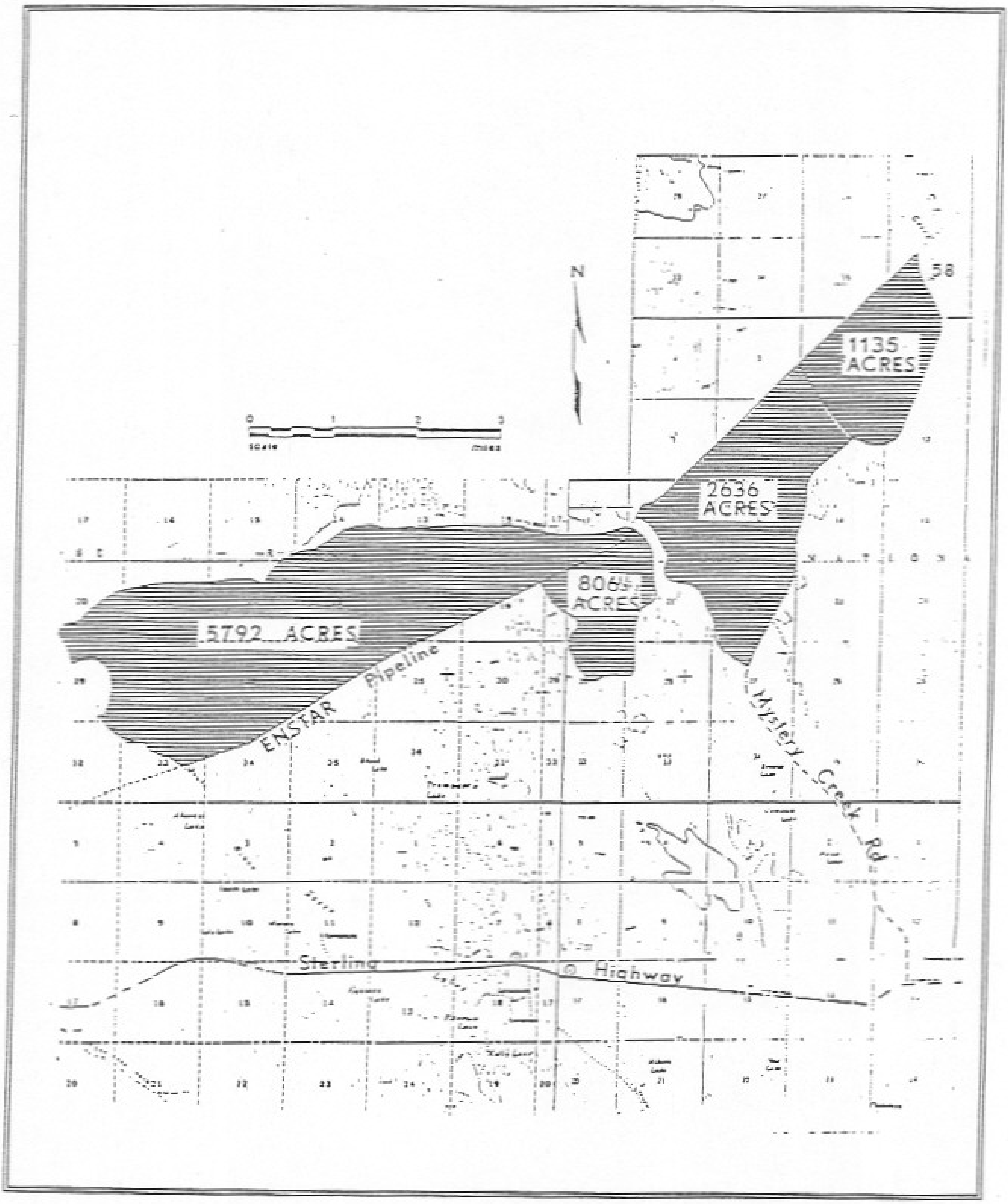

Figure 6. Proposed habitat treatment areas for the five-year period from 1996 through 2000, Mystery Creek Road vicinity, Kenai National Wildlife Refuge.

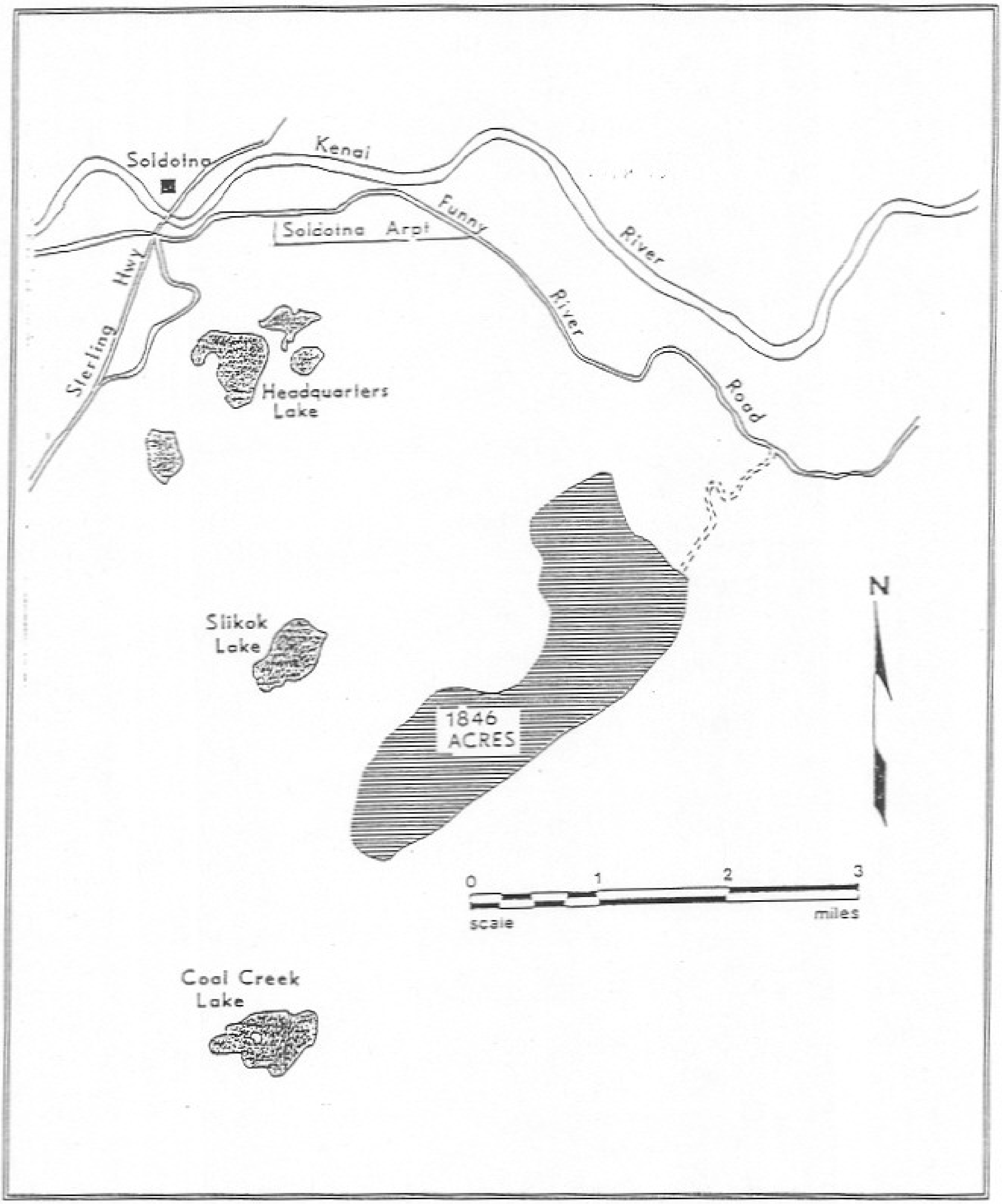

Figure 7. Proposed habitat treatment areas for the five-year period from 1996 through 2001, Funny River Road vicinity, Kenai National Wildlife Refuge.

powerlines, pipelines, improvements); 7) smoke-sensitive features; and 8) snow depths. The refuge has PC ARC (version 3.4D Plus) for its GIS system. Base maps are currently available. A vegetation map has been identified as a high priority at the refuge's Biological Review in 1993.

Vegetation monitoring Evaluation of the overall effectiveness of the habitat management program and refinement of techniques will require establishment of permanent plots in all prescription areas. Photo stations and standard techniques (Daubenmire 1959) will be used to sample vegetation before and after treatment. Data will also be collected on the parameters of the treatment itself for correlation with these measured results.

Moose browse utilization measurement There is not a consensus among wildlife biologists on optimal or range-damaging threshold levels of utilization of the different browse species on the Kenai Peninsula. Past studies have indicated, however, that preferred browse species such as willow can be reduced or removed from stands by browsing (Oldemeyer *et al.* 1977, Oldemeyer 1981). Standard moose browse utilization survey techniques will be used on a representative sample from each complex of habitat management units to monitor browsing intensity and any related vegetational changes.

Evaluation and Selection of Habitat Management Techniques

Habitat management techniques available to convert mature or advanced seral forest stands into early seral stands include clearcut logging, mechanical disturbance such as slashing, chaining, or crushing, and prescribed burning. Managed wildfire is not considered an option due to its unpredictability, inherent danger, and the current U.S. Department of Interior prohibition of its use to achieve land management objectives (U.S. Department of Interior Departmental Manual 910 DM 1). Over the past 35 years, each of these methods except the latter has been tried on the KNWR, and each has met with a high degree of success in terms of producing winter forage for moose (Oldemeyer and Regelin 1984). The advantages and drawbacks of each of these technologies are briefly described below.

Timber harvest The benefits to moose populations of the creation of forest openings through logging are well established (Peterson 1955, Peek *et al.* 1976, Telfer 1972). The potential of logging to produce the desired large acreages of seral habitat and fuel reduction on the KNWR, however, is limited by 1) the dynamic nature and small scale of the local forest products industry; 2) the scarcity and poor quality of commercial timber stands on the KNWR; 3) the difficulty of access to these stands; and 4) the long rotation period required for commercial timber production (resulting in intervals of low browse production from 65 to 155 years between repeat treatments). Consequently, less than 100 total acres of clearcuts have been completed to date, and this Plan does not consider logging as a viable habitat management tool at this time. Problems are created by roads into previously unroaded areas. However, the potential of timber harvest in specific forest stands will be evaluated on a case by case basis as individual project areas for Plan implementation are identified.

A program of public firewood and houselog harvest has resulted in 366 acres treated in the Funny River Road vicinity (GMS 15B) over a period of 11 years and 167 acres treated along Finger Lakes oilfield access road (GMS 15A) over 7 years. Both areas have yielded stands of blue joint grass which have limited the productivity of these sites for moose browse. Nevertheless, firewood cutting, in combination with periodic slash-disposal burning, will continue to be used until there is a shortage of easily-accessed mature stands of trees desired by woodcutters.

Other mechanical manipulation Various devices have been pulled, pushed, dragged, and rolled over the ground in older seral stands, in order to 1) reduce competing spruce trees; 2) stimulate basal and root sprouting of hardwood browse vegetation; and 3) to scarify the ground allowing for hardwood seedling establishment (Oldemeyer and Regelin 1984). Such methods have been successful in enhancing browse production here as elsewhere. Benefits include the shortest potential rotation time of any method, non-reliance on timber markets or vagaries of the weather, and non-sensitivity to concerns of the public (such as smoke or escaped fire). Drawbacks of this method are 1) the high cost at $30-$90+ per acre (ADF&G, Soldotna, AK, pers. comm.); 2) non-applicability in older stands with trees over 8-10 inches diameter at breast height; 3) a residual slash layer that adds to the organic forest floor to further retard nutrient cycling and insulate the ground, inhibiting plant growth; 4) a residue of viable seeds and seedlings of spruce which hastens the reestablishment of a competing spruce stand thereby shortening the productive life of the project; and 5) limitation to those areas accessible to the heavy equipment, supplies, and maintenance necessary for project support. Mechanical manipulation over frozen ground does not expose mineral soil which is needed for seedling establishment.

Prescribed fire Although prescribed burning has been practiced in other parts of the country, intentional stand-replacing burns in uncut northern forests are rare, with corresponding technology in its infancy. Most of the prescribed burns conducted on the KNWR to date have been treatments of slash residues from mechanical forest treatments, with lesser amounts of coincidental burning of standing timber within and adjacent to these project areas. Results of these burns have been encouraging from the standpoints of safety, operational efficiency, and habitat effects.

Advantages of prescribed burning over other disturbance techniques include 1) rapid and extensive consumption of organic materials resulting in improved seed germination and plant growth due to mineral soil exposure, accelerated nutrient cycling, and enhanced soil warming; 2) large areas may be manipulated in a short time; 3) remote areas may be manipulated without the necessity of roads and heavy equipment; 4) costs are generally much lower than mechanical methods (costs of previous KNWR projects have ranged from $6-$25 per acre, not including regular salaries of Service employees); and 5) results more closely resemble a natural event, from an aesthetic point of view.

Disadvantages to this technique include 1) seasonal windows of prescribed burning opportunity in this cool, damp part of Alaska are few and brief, and they generally overlap with the peak of the fire season, making prescribed burn scheduling a challenge; 2) the potential for escape of a prescribed burn into forest stands beyond the project area perimeter; 3) smoke may occasionally interfere with air commerce, highway traffic, public health, and/or outdoor recreational pursuits; and 4) fires of the size required to meet objectives are very visible and elicit negative reactions in many people.

Prescribed burning is a technical, complex, and highly regulated activity requiring specialized personnel with extensive training and experience requirements. Successful implementation of a prescribed burning program on the KNWR will therefore require maintaining a cadre of qualified personnel within the Service in Alaska and/or on the KNWR staff. Relying on help from cooperating agencies who do have fire suppression resources is likely to impede future burning plans. The former has not yet occurred because the Service does not have primary fire suppression responsibility on Service lands in Alaska. Other agencies understandably and necessarily put prescribed burning at a lower priority relative to their suppression responsibilities.

Despite these difficulties, the Service recognizes prescribed burning as the best available technique to meet vegetation management objectives on the KNWR, to be complemented where appropriate by other techniques. Experience with prescribed burning on the KNWR has indicated that the following needs must be addressed before stated objectives in this Plan can be achieved:

Interagency Cooperation

1. At the present time, the Service is dependent on other fire suppression agencies for some operational and many contingency resources to implement prescribed burn plans. More support is needed at upper administrative levels of all involved agencies, as well as a consensus among agencies on how to prioritize this function relative to the other obligations. The groundwork for this cooperation has been laid by the development of a multi-agency Prescribed Fire and Fire Effects Working Team by the National Wildfire Coordinating Group at both the national and regional levels.

Funding Needs

2. The Service's budget process must provide reliable longterm prescribed burn project funding, which recognizes that Plan implementation will not be possible during some years due to unfavorable environmental conditions existing throughout the short fire season. Some funds should be dedicated to 1261 activity (refuge) in addition to 9120 (fire) funding because a primary purpose of this Plan is habitat manipulation for wildlife.

KNWR Staffing Needs

3. The KNWR should minimize its dependence on local suppression organizations by hiring people with fire qualifications and experience for seasonal biological technician and ranger positions whenever possible and by continuing to provide training opportunities for permanent employees. The KNWR filled three permanent positions in 1993, Fire Management Officer (FMO), habitat biologist, and ecologist. KNWR staff with primary responsibility for implementing the habitat management program currently consist of the FMO and one seasonal (May 1-September 1) GS-6 biological technician who is paid with emergency fire presuppression funds. The FMO, in addition to directing implementation of this Plan, has standard duties in support of the Service's fire management program at the local, regional, and national level. Implementation of this Plan will require, at a minimum, a 6 person burn crew. These positions will include two GS-6 and four GS-5. These additional positions need approval and funding.

Training Needs

4. Given the few opportunities for Service employees in Alaska to participate in prescribed burning activities, the Service must capitalize on training and experience opportunities related to prescribed fire available in other regions. Some other regions have long and active burning seasons that do not overlap with the burning season in Alaska. This offers opportunities for inter-regional cooperation to the benefit of the Service and all participants. Without such mobility, some Service personnel in Alaska may never become qualified to fill key roles on prescribed burning teams. A significant portion of the regional fire training budget must be allocated for inter-regional projects to provide opportunities for Service personnel in Alaska to be signed off for the various task, skill, and knowledge elements required for prescribed fire positions, as outlined in the "Prescribed Fire Training and Qualifications Guide for Curriculum Development," prepared in 1989 by members of the National Wildfire Coordinating Group and adopted for use by the Service and other member agencies.

Public Information and Education

5. Public support for prescribed burning on the KNWR is crucial if the program is to survive any

escapement or smoke management problem. The Service will provide ample opportunity for public comment during the review process for this Plan. In addition to this initial public input process, Service news releases will brief the public on upcoming burns during the current season, and periodic stories will describe the progress and effects of the program. Coverage of prescribed burning activities on the KNWR must be extended to reach Anchorage-area residents since even a burn that is implemented perfectly will be visible in Anchorage. Continuing public education, utilizing programs in schools and universities and presentations in public forums, is also essential to successful Plan implementation. The Service's recently developed Fire Curriculum provides an excellent tool for public education.

Escapement and Smoke Management

The Service recognizes the potential for fire escapement beyond prescribed burn project boundaries and for smoke negatively impacting air quality in Kenai Peninsula communities and Anchorage as the main drawbacks of using prescribed burning as the primary habitat management tool on the KNWR. Wildfires resulting from escaped prescribed fires could threaten lives, cause damage to and loss of private property, and may have undesirable effects on biodiversity on the refuge and public use of refuge resources. Smoke associated with prescribed burning is of particular concern because of the relatively high level of inhalable and respirable particulates produced and the associated potential negative impacts to public health. Smoke can also interfere with air commerce and highway traffic.

The Service will minimize the potential for fire escapement by emphasizing prevention. Approved Prescribed Burn Plans (which provide a detailed description of fire prescription parameters under which ignition can occur), a holding plan, and a contingency plan listing all available contingency resources are required for all projects. Each project will be closely coordinated with the Alaska Division of Forestry, the agency with fire suppression responsibilities on the Kenai Peninsula.

The Service will minimize smoke-related problems associated with prescribed burning activities by complying with all State of Alaska Air Quality Regulations (18 AAC 50), Section III-H October 1983 Revision to the State Air Quality Plan, Alaska Department of Environmental Conservation (ADEC) Open Burning Policy and Guidelines, and all ADEC permitting procedures. Individual projects, by virtue of the Prescribed Burn Plan, will address all specific requirements of 18 ACC 50 and ADEC permit specifications. The Service intends to maintain air quality in smoke-sensitive areas during prescribed burning activities above Federal and State of Alaska-mandated minimum standards. The Service recognizes the need to acquire an Alaska Statute 16.05.870 anadromous fish stream permit before entering a designated anadromous fish stream with equipment in support of prescribed burns.

Past prescribed burning activities on the KNWR have been conducted successfully without escapement, indicating this management tool can be used safely. In 1987, however, despite strict compliance with ADEC's Open Burning Permit stipulations, an unforseen atmospheric inversion resulted in smoke from a prescribed fire on the KNWR reaching Anchorage where it reduced air quality, and significantly reduced visibility on the Sterling Highway between Cooper Landing and Sterling. Both fire escapement and smoked-related problems are inherent risks which must be understood and accepted by all involved agencies and the general public, if prescribed burning is to be used on the KNWR.

The Service accepts the inherent immediate risks associated with the use of prescribed burning as a habitat management and fuels reduction technique on the KNWR due to its longterm benefits to refuge resources. In the absence of forest fuels management, a catastrophic wildfire on the Kenai Lowlands is likely to reoccur sometime in the future. The deleterious effects to the general public and to refuge resources of such a fire are potentially far greater than those that might occur in association with prescribed burning, due to the extreme environmental conditions under which such a fire is likely to occur (conditions which would preclude prescribed burning) and the difficulty and expense of successfully suppressing such a fire.

Effects of Habitat Manipulation on Other Wildlife

The habitat use patterns of species other than moose on the KNWR also has to be recognized in each habitat prescription in order to maintain and enhance biodiversity. Some of these known patterns include:

1. Use of unburned, mature stands, particularly white spruce-birch-aspen stands on ridges within existing burns as:
    - Den sites (wolves, lynx, black bears)
    - Thermal cover (moose)
    - Feeding sites (black bear)
    - Nest sites (bald eagles, other raptors, large birds)

2. Habitat requirements of some neotropical migrant birds which are adapted to late successional stage or climax forest communities are absent from early successional forests.

3. Use of mature stands for species such as red squirrels, spruce grouse, and porcupines which are important alternative prey for lynx during lows in the snowshoe hare cycle.

Fire prescriptions will be designed to ensure that some mature stands will survive prescribed fires and known den and nest sites will be avoided. It is also recognized that there may be other habitat values associated with other wildlife species that may have to be addressed in future vegetation management prescriptions.

Details of Five-year Work Plan

Five-year work plan The tentative schedule for implementation and monitoring of habitat projects is outlined in Table 4. Note that the first four lines refer to existing disturbances that will be monitored. Mystery Creek and East Fork comprise the treatment area depicted in Figure 6, and Funny River II through V are to be selected from the treatment area depicted in Figure 7.

Five-year estimated budget Table 5 presents an estimated budget for the first five years of implementation of the habitat management portion of this Plan. Regular salaries of permanent full time staff included in present base funding are not included in this table.

Annual schedule Table 6 lists a typical annual work schedule for implementing the Plan's preferred alternative. It does not include the recommendations presented in the Research section of the Plan. These will be proposed at a later date, and may be addressed cooperatively with other agencies.

Table 4. Schedule for implementing prescribed burns and monitoring revegetation of habitat disturbances, 1996 to 2001.

Disturbance Name	Acres	Burn Year	*Min. # of Perm.Plots Daub.	FMH	Years for surveys Veg. Surveys Daub.	FMH	Plot Photos	Browse Surveys
Skilak Loop I	1200	1984	10		96,01		96,01	97,00
Lily Lake	700	1986	10		97		97	97,00
Skilak Loop II	1700	1987	10		96,01		96,01	96,99
Pothole Lake	7900	1991	4	6	96,01	99	96,01	97,00
Mystery Ck III, IV,V, and VI	3771	1996	8	24	96,01	99	99	96,99
East Fork & Mystery Ck I and II	6598	97/98	2	12	98	96-98	96	96,99
Funny River II	600	1999		5		96	96	97,00
Funny River III	400	2000		5		96	96	97,00
Funny River IV	400	2001		5		97	97	98,01
Funny River V	400	2001		5		97	97	98,01

* Daubenmire Plots have a permanent starting point with 50 randomly located stops to sample vegetation. FMH (Fire Monitoring Handbook) is a National Park Service methodology created in 1992. FMH plots are permanent 20 meter x 50 meter plots to sample vegetation and fuels.

Table 5. Budget (thousands of dollars) for implementation of preferred alternative of habitat management portion of the Plan, FY96 to FY98. Permanent full time salaries are not included.

Item	Funding Source	Fiscal Year 1996	1997	1998
Personnel:				
Bio Tech GS6 (2)	9110	1.0 FTE	1.0 FTE	1.0 FTE
Bio Tech GS5 (4)	9110	2.0 FTE	2.0 FTE	2.0 FTE
New Equipment:				
Pickup Truck	91XX		11.0	
Misc. Equip.	9110	3.0	3.0	3.0
Prescr. Fire Monitoring	1261	30.5	34.0	36.0
Habitat Mapping	1261	20.0	25.0	30.0
Special Studies	1261	60.0	63.0	65.0
Prescribed burn	9120	62.0	50.0	30.0
Prescribed burn	1261	0.0	10.0	30.0
TOTALS	91XX	65.0	64.0	33.0
	1261	110.5	132.0	161.0

Assessment of Moose Population Status

Monitoring Numerical Moose Population Trends

The following are recommendations for future aerial moose surveys on the KNWR. Moose density and composition surveys on the KNWR in GMU 15 will be conducted cooperatively with ADFG and will utilize GMS and refuge boundaries to define survey areas.

Densitv Survevs Aerial moose density surveys will continue to use techniques described by Gasaway *et al.* (1986). Monitoring of moose populations on the KNWR will be most intensive in GMS 15A. Density surveys will be conducted at 3-year intervals in this management unit. Consecutive-year

surveys could be conducted in the event of unusual occurrences (e.g., an extremely severe winter) which might result in immediate and major changes in total population. If deemed necessary, consecutive-year surveys over an extended period will be conducted to comprehensively assess the impacts of management activities (habitat enhancement, harvest strategies) on moose population dynamics. Population estimates will also compliment research activities aimed at refining our understanding of moose-habitat, moose-weather, and moose-predator interactions.

Table 6. Annual work plan for typical year of Plan implementation, Kenai National Wildlife Refuge, 1996 to 1998.

Month	Activity
Oct.-Feb.	Order and receive new and replacement equipment and supplies
Nov.-Mar.	Develop burn plans for coming fire season
Feb.-Mar.	Fire training nominations sent to fire training organizations
Jan.-Feb.	Set up or renew Cooperative Agreements with other agencies for assistance with burn plan implementation
Feb.-Mar.	Hire seasonal employees
Feb.-Mar.	Apply to AK Dept. of Environmental Conservation for open burning permits for prescribed burning
April	Seasonal employees come on duty
May-June	Conduct seasonal training of fire personnel
May-June	Maintain and test fire equipment
May	Conduct browse utilization surveys
May-July	Conduct fire prescription baseline monitoring field work
May-Aug.	Monitor site characteristics in potential burn sites in Wilderness and Minimal Management areas
June-Aug.	Do pre-burn site preparation (hydroaxe work, perimeter burning, drafting chance improvement, perimeter marking, fuel measurements)
June-July	Conduct current year prescribed burns
July-Aug.	Conduct post-burn revegetation plots
August	Conduct post-burn evaluation for current year burns according to burn plans
Aug.-Nov.	Compile and analyze annual field data from prescription baseline monitoring, revegetation plots, and browse surveys.
September	Seasonal employees off duty
All year	Build GIS habitat map and complete necessary field work for ground truthing.

Density surveys in GMS 15B and GMS 15C will be conducted on a staggered basis every fifth year. Scheduling of density surveys in these management subunits will be reassessed as necessary.

Composition Surveys Although of much value, the among-year comparability of moose composition data on the KNWR has been compromised by several factors. Although unfavorable environmental conditions such as lack of adequate snow cover have occasionally restricted survey activities, non-systematic techniques and between-year inconsistencies in survey effort, timing, and areas surveyed are most responsible. Future moose composition surveys on the KNWR must be standardized to maximize the value of the data collected. The sex and age structures of various

KNWR moose populations will be determined by fall composition surveys and this information will be used jointly by ADF&G and KNWR to assess and direct area-specific harvest management strategies.

Recent modifications to composition survey techniques are currently in use in other areas in Alaska. They provide statistically valid estimates of observable moose and of age and sex components of moose populations (E. Becker, ADF&G, pers. comm.; M. McNay, ADF&G, pers. comm.) These techniques will be evaluated and adopted if appropriate for the KNWR. Fall composition surveys will be conducted annually on the KNWR in GMS's 15A, 15B, and 15C.

Habitat Evaluation

Moose winter browse availability and use will continue to be monitored with browse utilization surveys. Research will be proposed to monitor revegetation patterns and assess habitat quality in prescribed burn areas. Determination of browsing intensities compatible with maintaining high quality habitat over the longest possible period of time will also be a primary objective of proposed studies.

Direct Animal Assessments

The Service and ADF&G will need to develop a new cooperative agreement concerning the Kenai Moose Research Center. The old agreement expired several years ago. Future cooperative projects will best be addressed by a new agreement. Research is ongoing at the Moose Research Center to assess the use of body composition and genetic variability as indices of the general health and vigor of moose populations. The KNWR will assist ADF&G with systematic collection of necessary tissue samples from harvested and road-killed moose necessary for these analyses.

Moose Population Composition Objectives/Regulation of Harvest

The established history and current levels of consumptive use of moose on the KNWR warrant careful consideration of the needs of this user group. Harvest of moose on the KNWR will continue to provide wildlife-related recreational opportunity and a valuable food source for humans. Concurrently, the impacts of various harvest strategies on moose population dynamics must be carefully assessed. Finally, moose harvest management on the KNWR should be directed by the degree of success attained with planned habitat management activities and the occurrence of unplanned events such as wildfires and severe winters, both of which will have significant impacts on moose population dynamics.

Moose Population Composition Objectives

Harvest regulations in accessible portions of the KNWR (GMS 15A and 15B-West) should optimize recreational hunting opportunity while maintaining bull:cow ratios at objective levels and a balanced male age structure. Harvest regulations on that portion of the KNWR within GMS 15B-East and GMS 15C should maintain higher bull:cow ratios and greater percentages of prime-age bulls than those on the Kenai Lowlands to maintain established habitat use and movement patterns, especially as related to breeding behavior during the fall rutting season. These objectives are also consistent with the overall Service objectives of maintaining naturally-regulated moose populations and wilderness recreational opportunities in these portions of the KNWR.

Post-hunting season moose population composition objectives on KNWR-lands within GMS 15A, GMS 15B, and GMS 15C are presented below. The Service recognizes that administrative boundaries are artificial when considering moose population biology, that composition of moose populations in the areas defined by these boundaries in a given year can be influenced by a variety of factors, and that obtaining statistically-valid estimates of the various age and sex components of moose populations on an annual basis is difficult. These objectives are therefore presented as general management guidelines. They are meant to help maintain biologically-sound sex and age structures in moose populations and to meet the Service's mandate of managing for natural diversity in wildlife populations and habitats, while allowing for varying levels and types of public use in different areas on the KNWR.

Northern KNWR	
GMS 15A	25-30 bulls:100 cows
Skilak Loop SMA	40 bulls:100 cows
Central KNWR	
GMS 15B-West	25-30 bulls:100 cows
GMS 15B-East*	40-60 bulls:100 cows
Southern KNWR	
GMS 15C-21 (Caribou Hills)*	40-60 bulls:100 cows
GMS 15C (excluding Caribou Hills)	25-30 bulls:100 cows

* These more natural moose populations in wilderness areas historically and presently contain not only more bulls, but more older, trophy-class bulls.

Harvest Regulations

Careful assessment of longterm population trends and the factors influencing moose population dynamics are prerequisite to recommendation of harvest strategies. The ADF&G has conducted a comprehensive review of the impacts of the first five hunting seasons (1987-1991) under the spike-fork/>50" or three brow tines selective harvest system on the Kenai Peninsula (Schwartz *et al.*,1992). The current regulation has been successful in helping to meet moose population composition objectives on the KNWR. Bull:cow ratios are gradually increasing in GMS 15A and GMS 15B-West, and the composition objectives outlined above are currently being met in the GMS 15B-East and GMS 15C portions of the KNWR. The Service therefore recommends continuation of the current or similar selective harvest regulations.

Several optional selective harvest strategies for bull moose are presented below for consideration. Final harvest regulation recommendations, including any recommendations for antlerless harvests, will be developed cooperatively with the ADF&G upon completion of their aforementioned review of the current regulations. Recommended harvest strategies will also consider all input received during the public review process for this Plan. Most optional strategies presented apply to GMS 15A where moose population data is most complete and analysis of the effects of past and current harvest regimes is possible. Systematic assessments of moose population composition and trend are needed in the remainder of the KNWR in order to conduct similar analyses and recommend harvest strategies to meet objectives on KNWR lands in GMS 15B-East and GMS 15C. The Service recommends that current harvest strategies remain in effect in these portions of the KNWR at until such data is available.

Harvest Strategy 1 Maintain current selective harvest regulations for bull moose in GMS 15A, GMS 15B-West, GMS 15C, and Skilak Loop SMA through 1995. Harvest is restricted during the August 20 - September 20 general hunting season to bull moose having spike/fork antler configurations on at least one side or 50"+ antler spread or three brow tines on at least one side. Alaska Board of Game expanded the general hunt by adding 12 days to the beginning of the season in 1993.

Justification

1) Bull:cow ratios and the number of prime-aged bulls in the moose population have gradually increased in GMS 15A.

2) Protection of yearling bulls with three-point or larger antler configurations may have increased population quality by allowing more of these theoretically "superior" animals to mature and breed.

3) The number of large-antlered bulls available for harvest and harvested in GMS 15A has increased since 1987.

4) The number of teen and prime-aged bulls (medium- and large-antlered) available for nonconsumptive uses has increased.

Harvest Strategy 2 Implement a general hunt for bull moose having a spike or forked antler configuration on at least one side and a limited-entry (drawing permit) hunt for any bull in GMS 15A. This strategy withdraws 50"+ or three brow tine bull moose from the legal bull category during the general moose hunting season in GMS 15A. The number of "any bull" permits allocated annually will be directed at maintaining a 25-30 bulls:100 cows sex ratio and a balance aged structure which includes a minimum number of prime-aged bulls in GMS 15A.

Justification

1) A limited-entry permit hunt for any bull provides management agencies with a direct approach for maintaining the 25-30 bulls:100 cows sex ratio and a balanced male age structure which includes a minimum number of prime-aged bulls in GMS 15A. Theoretically more vigorous yearling bulls and teen bulls are still protected.

2) Numbers of moose harvested in GMS 15A will not decline under this regulation. Spike/fork bulls comprised 70.8% of all bull moose harvested in GMS 15A from 1987-92. Habitat management activities aimed at improving reproductive performance and calf survival will be most intensive in GMS 15A, resulting in consistent availability of yearling spike/fork bulls for harvest (exceptions would occur in hunting seasons following severe winters).

3) The increased number of teen and prime-aged bulls will benefit nonconsumptive users.

4) Dropping the 50 inch/three brow tine requirement in the general hunt will substantially simplify the selective harvest regulation and consequently improve compliance.

5) The "any bull" limited-entry hunt will provide quality hunting opportunities and allow selection by permitted hunters for bulls of any age or bearing any antler configuration.

Harvest Strategy 3 Implement a general hunt for bull moose having a spike or forked antler configuration on at least one side and a post-rut hunting season for 50"+ or three brow tine bulls in GMS 15A. This strategy withdraws 50"+ or three brow tine bull moose from the legal bull category during the general moose hunting season in GMS 15A. The post-rut hunting season would involve either a registration hunt or a limited-entry permit hunt. Length of the post-rut hunting season or the number of permits allocated would be directed towards maintaining a 25-30 bulls:100 cows sex ratio and an adequate number of prime-aged bulls in GMS 15A.

Justification

1) Restricting harvest of large-antlered bulls prior to the rut in combination with protection of teen bulls will ensure a balanced male age structure which includes a minimum number of prime-aged bulls present during the breeding season. Theoretically more vigorous yearling bulls are protected.

2) Registration or limited-entry permit post-rut hunts for large-antlered bulls provides management agencies with a direct approach for maintaining the 25-30 bulls:100 cows sex ratio and a balanced age structure in GMS 15A.

3) Numbers of moose harvested will not decline under this regulation. Spike/fork bulls comprised 70.8% of all bull moose harvested in GMS 15A from 1987-92. Habitat management activities aimed at improving reproductive performance and calf survival will be most intensive in GMS 15A, resulting in consistent availability of yearling spike/fork bulls for harvest.

4) Dropping the 50 inch/three brow tine requirement in the general hunt will substantially simplify the selective harvest regulation and consequently improve compliance.

Human-caused mortality, including harvest, is most likely to be compensatory to natural mortality when moose populations are at or exceed the nutrient-climate ceiling (Theberge 1990). Conversely, harvest mortality is more likely to be additive to natural mortality and contribute to limiting moose population growth when moose populations are well below nutrient-climate ceilings.

Harvest of antlerless moose (cows and calves) may be necessitated on those portions of the KNWR in GMS 15A and GMS 15B-West to maintain habitat quality and diversity in newly-created early seral habitats. Antlerless harvests would be least appropriate before and during peak-forage production in newly-created early seral habitats, when moose populations are likely to be below the nutrient-climate ceiling and reproductive success and the population's rate of increase are potentially highest. Because forage production in burned areas generally peaks 8-15 years following fire on the Kenai Peninsula, antlerless harvests more likely would be appropriate during the latter part and after this period.

Systematic evaluation of browsing intensity in newly-created early seral habitats in combination with monitoring moose population status will be required to determine the need for future antlerless moose harvests. The occurrence of high road-killed mortality and the existence of a multiple predator-moose system on the KNWR warrant careful assessment of antlerless harvests. Antlerless moose harvests should occur only when the following conditions are met: 1) moose populations are believed at or above nutrient/climate ceiling and harvest is needed to prevent overutilization of food supplies; 2) predator and scavenger species dependent on moose are not food-stressed as determined by monitoring their population status, annual reproductive success and other parameters; and 3) predictive modeling of moose population dynamics indicates a harvestable surplus of antlerless moose exists.

Restrictions limiting antlerless harvests to specific areas, i.e., a zonal management strategy, may be appropriate in areas where planned habitat management is occurring to prevent overutilization by moose of winter browse in these small areas.

The only antlerless harvest currently occurring on the KNWR is the limited-entry (30 permits by drawing) in the Skilak Lake Wildlife Recreation Area. The Service recommends cooperative review with the ADF&G of this hunt and the parameters which set it in place. In 1995, an additional 20 transferrable permits for antlerless moose were issued. Habitat in areas managed using tree crushing and prescribed burning in the mid-1980s will soon enter the period of prime forage production and nutritional quality. Potential benefits to moose and increases in calf production and survival will be greatest during this period.

Other Mortality Sources - Predation and Highway Accidents

Predation

As the principal ungulate species on the KNWR, moose are the primary food source for wolves and are an important prey item for black and brown bears and may provide an important seasonal food source for bald eagles and other avian scavengers, lynx, coyotes, and wolverine. Maintaining moose populations at densities capable of sustaining viable and healthy mammalian and avian predator and scavenger populations is therefore a major objective of moose management on the KNWR. The Service will continue, and expand as necessary, scientific study and monitoring of predator and scavenger species populations on the KNWR which depend on moose as a major food source.

Recent moose population dynamics in GMS 15A have shown that a moderate density (1-3 moose/km^2) moose population can increase in a multiple predator-moose system when habitat conditions become favorable in early seral forests created by large-scale disturbances. The highest post-1969 wildfire population estimate for GMS15A was 4,352 in 1982. Winter moose densities in the 1969 burn remained high (3.5-4.4 moose/km^2) 13-21 years post-fire (Loranger, *et al.* 1991). The potential for significant declines in moose densities as forest succession proceeds in the 1969 burn and the concurrent impacts on predator populations, especially wolves, of such declines underscores the importance of maintaining early seral forests in GMS 15A. Low density moose populations, which have a greater potential of being controlled by predation, may not respond to the creation of favorable habitat. The ability of the KNWR habitat management program to provide for sustained numbers of moose may therefore depend on the timing of its implementation. Potential for attaining this goal is greater while moose densities in GMS 15A remain relatively high due to the still-favorable habitat conditions in the 1969 burn.

The moose population increase which occurred following the 1969 wildfire also coincided with relatively high annual harvest rates of wolves (Schwartz and Franzmann 1989). Concern for high annual harvest rates of wolves during this period led to the development of a cooperative Service-ADF&G Wolf Operational Management Plan for GMS 15A. This operational plan, among other population parameters, set a post-trapping season wolf population objective. Annual harvest rates of wolves from 1988-1992 declined significantly, and the GMS 15A wolf population has stabilized above the objective. Wolf populations in GMS 15A currently could support higher annual harvests based on the assumptions of the operational plan, and may be desirable in light of declining habitat quality for moose. It is imperative that accurate wolf population estimates continue to be obtained in GMS 15A. The upcoming development of a statewide Strategic Wolf Management Plan by the ADF&G, which will include extensive interagency and public involvement, will provide an appropriate forum for addressing moose-predator interactions, wolf population objectives, and management options on the KNWR.

Highway Accidents

The number of moose killed annually on Kenai Peninsula roads has increased dramatically in recent years (Del Frate and Spraker, 1991). During the winter of 1994-95, a record-high 335 moose were killed on Peninsula roadways. Three ongoing processes potentially will increase roadkills in the near future. Loss of wintering habitat as the 1969 burn matures in GMS 15A may concentrate more moose in the Kenai-Soldotna-Sterling area. The realignment and widening of the Sterling Highway through this moose wintering area will most likely result in increased vehicle speeds, a prime factor affecting the incidence of roadkills. The increased development and land clearing along the road corridor will draw more wintering moose into developed areas.

Highway accidents involving moose constituted a major mortality factor for reproductive-age female moose in two areas on the Kenai Peninsula according to a study by Bangs *et al.*(1989). It is most likely an additive form of mortality since this sex and age group is believed the least susceptible to natural mortality sources such as predation, severe winters, and disease, and only very limited harvest of cows occurs on the Kenai Peninsula. Cow and calf moose that winter in off-KNWR developed areas are probably less susceptible to predation (low wolf densities) and winter stress (plowed roadways decrease the energetic costs of mobility and development has created favorable habitat conditions), further increasing the likelihood that roadkills constitute an additive form of mortality.

Given the increasing public safety hazard from moose-vehicle collisions and the potential negative impacts of vehicle-caused mortality on KNWR moose populations, the Service recommends continuation and expansion of the "Give Moose a Brake" public awareness campaign currently being cosponsored by the ADF&G and the Alaska Department of Public Safety to reduce roadkills on the Kenai Peninsula. To the extent possible, habitat management on the KNWR will attempt to concentrate wintering moose away from roadways and residential areas. The Service should support a joint multiagency-public approach to address the problem. Potential actions to reduce roadkills, such as reducing legal vehicle speed limits during winter, may require legislative action. The Service believes formation of a steering committee to develop recommendations addressing current conditions and guidelines for future road construction and/or improvements is appropriate at this time.

Research/Management Information Needs

The following projects are identified as priorities for addressing current informational needs related to moose management on the KNWR.

Habitat Management

Prescribed fire information needs

The technical problems faced by managers in attempting to produce desired vegetation changes through prescribed fire can be divided into two broad categories: those relating to site selection (site variables) and those relating to the way in which the selected site is treated (prescription variables).

<u>Site variables</u> Each of the following site characteristics has some effect on the quality of habitat to be produced and/or the safety and cost-effectiveness with which the site may be treated:

- **Topography** (elevation, slope, and aspect)
- **Site location and juxtaposition with other fuel types**
- **Vegetation characteristics** (species composition, stand age, stem density, crown closure)
- **Mineral soil type**
- **Organic layer (duff) depth**
- **Soil drainage** (moisture regime)
- **Fuel characteristics of vegetation complexes**

Topography is similar enough from site to site on the Kenai Lowlands that specifically addressing it as a selection factor is unnecessary. **Site location and juxtaposition with other fuel types** relate to safety and feasibility of a project. Consideration of this variable is largely a matter of experience. In order to maximize efficiency, studies are needed on the last five variables. Proposals should be developed within the first two years of Plan implementation, so that resulting information will be available to aid in selecting sites for the second 5-year implementation period.

<u>Prescription variables</u> Once a site is selected, a wide range of results may be obtained depending on the prescription that is used in burning it. Prescription parameters may be divided into groups according to the objectives to which they apply:

Safety (minimizing escape potential and danger to burn crew members):

- **rate of spread**
- **fire intensity**
- **spotting potential**
- **season** (nighttime humidity recovery)

Minimizing smoke impacts:

- **duration of residual burning** (heavy fuel and duff moisture)
- **wind direction**
- **ventilation factor** (vs. size of burn)

Achieving desired effects on vegetation:

- **seasonal date** (plant phenology)
- **fire severity** (heavy fuel & duff moisture, lighting technique, pre-burn fuel treatment)

Minimizing cost per acre:

- **size of burn units** (economy of scale)
- **ignition techniques**
- **season** (late-season humidity recovery reduces containment and mop-up costs)
- **pre-burn fuel and perimeter treatments**

Some immediate information needs pertaining to burning prescriptions are 1) to obtain enough information on local fuels to facilitate adjustment of standard fuel models to more accurately predict fire behavior (**rate of spread, fire intensity, spotting potential**) for these fuels; and 2) to determine the fire severity (the depth of burn or percentage of organic forest floor removed) required to achieve revegetation objectives, what duff moistures will produce the required severity, and how currently available remote sensing techniques can be utilized to predict when the proper duff moisture levels are reached.

Some of these complex needs are currently being addressed on a preliminary basis through a study initiated by the KNWR in June, 1991, in cooperation with the U. S. Forest Service, Pacific Northwest Research Station. Ten one-tenth-acre plots were established in a 1947 burn upland black spruce regrowth stand and were sampled for soil and vegetation characteristics. They were then monitored for various weather and fuel moisture parameters. Three of the plots were burned under various conditions, with fire behavior and fuel consumption data collected during and after each test burn. This study should be expanded to include several different fuel complexes and continued over a minimum 5-year period. The addition of new staff members in the fire program and a committment to increase biological program funding will allow similar data gathering to occur with all prescribed fires on the refuge in the future. Other fire prescription parameters will be studied as the need becomes evident during Plan implementation.

Effects of browsing Both the quantity and nutritional quality of current annual growth produced by woody plants browsed by moose are influenced by the plants' age and history of browsing by moose and/or snowshoe hares. The production of secondary metabolites as a plant defense mechanism against excessive herbivory also influences nutritional quality and palatability of forage. Research to determine browsing intensity (as related to moose density) which results in maximizing nutritional quality and current annual growth production of forage over the longest possible period of time is needed.

The following topics are also recommended for future studies. Some topics will be attempted in cooperation with the U.S. Forest Service and possibly other federal and state agencies.

Fire frequency The frequency of wildfires, either natural or man-caused, is unknown and of great importance on the KNWR and Kenai Peninsula. Knowledge of vegetation dynamics and successional patterns following fire and the long term frequency of fire will be needed to establish prescribed burning rotation periods and the appropriate role of fire in wilderness areas on the refuge.

Blue joint grass Blue joint grass (*Calamagrostis canadensis*) has long been recognized as a formidable competitor of tree seedlings in the forests of southcentral Alaska, and is considered by the Forest Service and the Alaska Division of Forestry to be a limiting factor of primary concern in reforestation work in that region (S. Borchers, U.S. Forest Service, Idaho, and W. Wahrenbrock, Alaska Dept. of Natural Resources, Division of Forestry, pers. comm.). Question: What are the ecological relationships between fire and blue joint grass on the Kenai Lowlands, and how can the detrimental effects of this plant on the establishment of desired browse plant seedlings be minimized?

Spruce bark beetle Recent epidemic infestations by the spruce bark beetle (*Dendroctonus rufipennis*) have resulted in the death of nearly all mature white spruce in thousands of acres of pure and mixed white spruce stands on the KNWR. This is a catastrophic stand-replacing event without the rapid organic reduction and nutrient cycling characteristics of fire. Question: What are the relationships of spruce beetle-caused forest changes to the composition of the residual vegetative community and its animal inhabitants, and how should this event affect our vegetation management strategy?

Devil's club Devil's club (*Echinopanax horridum*) has been identified as an important food of black bears on the Kenai Lowlands. Schwartz and Franzmann (1991) noted that when this plant is removed from lowland plant communities by fire, it may not return to the site for at least 40 years. Question: What are the ecological relationships of Devil's club to fire, and how should we manage Kenai Lowland forests to maintain this flora component sufficiently to ensure continuation of its current status in the diet of the black bear?

Moose Population Management Studies

Priority 1 Design and implement (cooperatively with ADF&G) a population identity study of moose utilizing early seral habitats, including habitat management areas, road corridor, and residential areas in GMS 15A.

Objectives

1) To determine the movement patterns of moose utilizing early seral habitats, including "resident vs. migratory" status, seasonal patterns of use, and home range.
2) To determine age-specific survival and reproductive rates of moose utilizing early seral habitats for input into computerized population simulation models.
3) To assess the relative importance of factors contributing to moose use of habitat management, road corridor and residential areas.
4) To develop recommendations for reducing the number of moose-vehicle collisions.

Priority 2 Develop cooperatively with ADF&G a predictive computerized population simulation model for Kenai Peninsula moose popuplations.

Objectives

1) To project moose population responses to management activities such as habitat

manipulation and harvest regulations or to natural events such as wildfires or extreme weather conditions.

2) To evaluate management strategies in light of predicted responses of moose populations.

MOOSE MANAGEMENT ON THE KNWR - 1941 to PRESENT

Habitat Management

The last one hundred years on the Kenai Lowlands have been marked by dramatic changes in forest habitat caused by large, mostly human-caused wildfires and post-fire forest succession (Lutz 1960, Spencer and Hakala 1964). These alterations have resulted in dramatic fluctuations in populations of moose and other herbivores in response to changes in availability of winter forage (woody browse) and have been responsible for some very expensive fire suppression efforts (Alaska Fire Service fire reports, 1969 and 1974).

Habitat management on the KNWR has been aimed at creating and maintaining early seral habitats similar to those created by fire and other perturbations. To date, a total of 16,400 acres (6,640 ha) has been manipulated. Mechanical crushing and prescribed burning account for most of this total (Table 7).. A detailed review of the history of habitat management on the KNWR is presented by Oldemeyer and Regelin (1987). Earliest efforts to improve habitat began in 1956. From 1956 to 1968, a total of 6100 acres (2,468 ha) were managed using techniques that included plantings of

Table 7. History of habitat management on the Kenai National Wildlife Refuge, 1956-present.

Year(s)	Location	Method	Area (acres)
1956-1968	Slikok Lake, Mystery Creek Rd.	Willow plantings, handpulling spruce, bulldozing	6100
1974-75	Willow Lake	Mechanical crushing	1100
1975-76	Moose Res. Center	Mechanical crushing	1300
1976-78	Mystery Creek Rd., Watson Lake	Mechanical crushing	4300
1984, 1987	Skilak Loop	Mechanical crushing[a] and prescribed burning	2250
1986	Lily Lake	Mechanical crushing[a] and prescribed burning	700
1988	Funny River Road	Prescribed burning	650

[a] done by the Alaska Department of Fish and Game

willow, handpulling of spruce, and clearing with a bulldozer with various blade attachments (Kenai National Moose Range Annual Narrative Reports, 1956-1968) (Table 7). Most management activities took place in the Slikok Lake area, an important historical moose wintering area located in the western portion of GMS 15B. The managed area was within the 4,000 acre (1,620 ha) Slikok Lake burn, which occurred in 1926. Smaller areas along Mystery Creek Road in GMS 15A were also managed during this period.

In 1970, the KNWR purchased three 40-ton Letourneau timber crushers to rehabilitate portions of the 1969 burn. From 1974 to 1978, the crushers were used to manage a total of 7,000 acres (2,710 ha) in four locations, all within the perimeter of the 1947 burn. In the Willow Lake area, 1,100 acres (445 ha) of mature and regrowth stands were crushed in 1974 and 1975. A total of 1,300 acres (525 ha), most of which was regrowth vegetation, was crushed adjacent to and south of the Moose Research Center in 1975-76. During the winters 1976-77 and 1977-78, 4,300 acres (1,740 ha) were crushed along the Mystery Creek Road and in an adjacent area east of Watson Lake. Most of this area consisted of regrowth stands.

Due to a change in Regional Service policy regarding mechanical tree crushers, the crushers stood idle until 1983, when two were transferred to and the third purchased by ADF&G. Over the next four years, a total of 3,550 acres (1,437 ha) of 1947 burn regrowth in three parcels were crushed by ADF&G in the Skilak Loop and Lily Lake areas. All but 600 acres (243 ha) were subsequently burned using prescribed fire. These fires, conducted by KNWR staff assisted by ADF&G, Alaska Division of Forestry, U.S. Forest Service, U.S. Bureau of Land Management, and U.S. Bureau of Indian Affairs personnel, served to reduce hazardous surface fuel loading as well as enhance habitat for moose.

The Letourneau tree crushers were surplused in 1988 by ADF&G, marking the end of large-scale mechanical manipulation using the crushers on the KNWR. Prescriptions were written for prescribed burning of two areas within the 1947 burn along the South Pipeline Road in GMS 15A, and for one public firewood area with several years of slash accumulation in GMS 15B. A total of 650 acres (263 ha) were burned in the firewood area in May 1988. The other two areas have not been burned due to unfavorable environmental conditions and staffing limitations during the summers of 1989-1994.

Assessment of Moose Population Status

Monitoring Moose Population Trends

Surveys to monitor moose populations on the Kenai are conducted by both ADF&G and KNWR. Survey's may or may not be conducted jointly, but survey results will be shared by the two.

Density Surveys

Aerial surveys to estimate numbers of moose on the KNWR were first conducted in 1949. From 1949 to 1964, this survey consisted of flying a series of north-south transects north of Tustumena Lake. In 1964, a survey utilizing stratified random sampling of 1 mi^2 sample units was instituted and allowed the calculation of a population estimate with known confidence intervals. Survey techniques were described in Evans *et al.* (1966). This estimate was generated for the area north of Tustumena Lake and west of the Kenai Mountains (equivalent to GMS 15A and GMS 15B). Sample units were placed into High, Medium, and Low moose density strata based on intuitive knowledge of moose distribution and overflights of the survey area. The quadrat sampling technique was utilized to estimate total numbers of moose north of Tustumena Lake from 1964 to 1982, although surveys were not conducted in all years. In 1987, a modified density survey technique, which also used stratified random sampling, integrated the variance associated with sightablity of moose into the population estimate, and maximized efficiency (Gasaway *et al.* 1986) was adopted. Larger sample units of approximately uniform size (10-15 mi^2) are stratified according to observed moose densities during overflights of the survey area immediately prior to the onset of the survey. Estimates were generated using this modified technique for GMS 15A in 1987, 1990 and 1995, and for GMS 15B in 1990 and 1996.

Composition Surveys

Aerial moose composition surveys have been conducted on the KNWR in most years since 1950. They are conducted as soon as snow conditions become favorable for visibility and before most bulls shed their antlers, i.e., from mid-November to early December. Survey areas of varying sizes were established by KNWR staff during the 1950s and early 1960s and were changed to correspond to GMS boundaries in the mid-1960s. Moose are classified into various sex and age categories and the information is used to index the population's sex composition (bull:cow ratio), reproductive success (calf:cow ratios, twinning rates), and recruitment (yearling bull:adult cow ratios).

Calving Season Surveys

Aerial surveys of the Moose River Flats area, a major calving area in GMS 15A, were conducted by KNWR personnel each year from 1957 to 1971 to assess annual reproductive success. The area was surveyed along a series of parallel transects. Five to 14 surveys were conducted annually between late May and mid-July to assess annual reproductive success using calf:cow ratios and twinning rates. Spring calf surveys (late May-early June) were conducted by ADF&G personnel in the 1969 burn in GMS 15A in 1982, 1983, 1988, and 1989.

Woody Browse Evaluation

Two major efforts to monitor changes in hardwood species composition and stem density following disturbance (wildfire or mechanical crushing) have been undertaken on the KNWR. Nine plots were established within the 1947 burn along the Skilak Loop Road and monitored in 1950, 1955, 1961, 1965, and 1977. Vegetation in 294 stands in mature forest, regrowth forests following fire (6 age classes of stands: 3, 8, 13, 30, 50, and 77 years), and regrowth forests following mechanical treatment on the KNWR were studied from 1976 to 1981 (Oldemeyer and Regelin 1987).

Surveys to determine levels of utilization of important woody browse species by moose have been conducted using a variety of techniques on the KNWR since 1950. Most recently, standardized browse utilization surveys developed by the ADF&G have been used to annually monitor forage plant species composition and the percentages of the previous year's current annual growth browsed by moose along 100-plant transects in the 1969 burn and recent habitat management areas.

Moose Condition Monitoring

The ADF&G has conducted several studies at the Kenai Moose Research Center to assess the use of physical status (weight, morphometric measurements, antler growth) and physiological indices as indicators of the condition of moose populations (Franzmann 1977). Among the physiological indices studied were blood parameters (packed cell volume, hemoglobin, calcium, phosphorous, and total protein), levels of minerals in hair, and bone marrow fat content. Ongoing investigations at the Moose Research Center are evaluating body composition and genetic variability as indices of population condition (C. Schwartz, pers. comm.)

Regulation of Harvest

Historical records indicate that regulation of the moose harvest on the Kenai Peninsula has shifted from conservative to liberal and back again in response to increasing and decreasing moose populations. The predominant management strategy to the present has been to direct harvest toward the adult male segment of the population. Antlerless moose harvests have occurred, primarily during the 1960s and early 1970s when moose populations on the Kenai Peninsula were probably at their highest in the last 50 years.

The earliest harvest records available for the Kenai Peninsula are from the 1948 hunting season. Moose populations were believed low at the time due to deteriorating range conditions (Spencer and Hakala 1964), and conservative harvest regulations were in place. One bull moose could be legally harvested south of the Kenai River from 1-15 September and from 1-5 December in 1948. The December late season was dropped in 1949, and from 1949-1955, one bull moose could be legally harvested from 1-20 September. Moose hunting was not allowed north of the Kenai River until 1955.

More liberal harvest strategies in response to increasing moose populations were first implemented in 1956. Favorable habitat conditions created by the 1947 wildfire were believed responsible for this population increase (Spencer and Chatelain 1953, Spencer and Hakala 1964). These changes included a longer early hunting season (20 August to 30 September) and the reestablishment of late season hunts. The first antlerless season on the Kenai Peninsula occurred in 1960. One hundred and fifty permits were issued for this hunt. Harvest of cow moose occurred in at least one of the GMUs on the Kenai Peninsula from 1960 to 1974.

Declining range conditions (Oldemeyer *et al.* 1977) and a series of severe winters (Bishop and Rausch 1974, Bailey 1978, Bangs and Bailey 1980) precipitated a decline in moose populations. Current theory suggests that predation is most likely to control a prey population when the prey population is well below the nutrient-climate ceiling. The data indicates that the moose population in GMS 15A in the late 1960's was probably at or above this ceiling. Predation may have accelerated the decline, especially in its latter stages, but probably was not a causative factor. The decline prompted more restrictive harvest regulations in the late 1960s and 1970s. Among changes were a shortened early season and elimination of late season and antlerless hunts. Harvest of cows was not allowed anywhere on the Kenai Peninsula from 1975 to 1979. Harvest of bull moose under an "any bull" regime remained in place throughout the Kenai Peninsula (except GMS 15B-East) through the 1986 season.

In 1975, GMS 15B was subdivided into GMS 15B-East, which encompasses the Tustumena Benchlands in the upland eastern portion of this management unit, and GMS 15B-West. Hunting was closed in GMS 15B-East in 1975 and 1976, and reopened in 1977 on a limited-entry basis. Forty permits were issued for any bull moose in 1977 and 1978 and the season extended from September

1-30. In 1979, a selective harvest strategy for trophy bull moose was instituted in GMS 15B-East. Harvest was restricted to bulls having 50-inch or greater antler spread or three brow tines on at least one side. The number of permits issued and season dates remained constant until 1982 when 100 permits were issued for each of two seasons. The early season hunt extended from September 1-20 and the late season from September 26 - October 15. The trophy bull moose hunt in GMS 15B-East has been similarly regulated since that time.

Conservative limited-entry cow hunts were reinstituted and occurred in 1983, 1984, and 1986, where moose numbers increased due to favorable habitat conditions created by the 1969 wildfire, in 1989 through 1994 in the Skilak Wildlife Recreation Area, and from 1980 through 1994 in the Portage-area in GMU 7.

Biological concerns for the potential impacts of low bull:cow ratios, potential loss of hunting opportunity, and male age structures favoring younger bulls in GMS 15A; addressing the KNWR's mandate of managing for "natural diversity"; and a recognition of the aesthetic value of more bulls in moose populations led to the development of a joint proposal by the Service and the ADF&G to the Alaska Board of Game in 1986 to implement a selective harvest program for moose on the Kenai Peninsula. The proposed regulation limited the harvest of bulls to those having spike or forked antler configurations on at least one side or 50-inch or greater antler spread or three or more brow tines on at least one side. The regulation was approved by the Board and was implemented during the 1987 hunting season in GMU 15 (except GMS 15B-East) and GMU 7. A special five-day archery-only hunt (August 25 - 29) for bull moose under the above antler restriction regulation was also instituted in 1987 in GMS 15A (except Skilak Wildlife Management Area) only. These regulations have remained in effect from 1987-92. In 1993, the Board of Game lengthened the season to August 20 to September 20 and dropped the archery-only hunt in GMS 15A.

Research/Management Efforts

The Kenai Moose Research Center was established from 1966 to 1969 and has since been operated under a cooperative agreement between the Service and the ADF&G. It is located on the Kenai Lowlands in the northern KNWR and consists of four one-mi^2 enclosures, housing and laboratory facilities. The primary purpose of its establishment was to study moose-habitat relationships. A wide range of research activities, including studies to determine movement patterns and identity of moose populations on the Kenai Peninsula, habitat carrying capacity as defined by the daily and seasonal nutritional requirements of moose, and the response of habitat to manipulation and browsing, to identify physical and physiological parameters which could be used to assess moose population condition, to test and develop new immobilization drugs and capture techniques, to assess the effects of predation on moose population dynamics, and to assess genetic variability in Kenai Peninsula moose have been conducted by the ADF&G at the Moose Research Center since its inception.

The Service conducted a telemetry study to determine the effects of winter seismic exploration on moose movements and use of two important wintering areas (1969 burn and Slikok Lake) on the KNWR from 1980 to 1982 (Bangs and Bailey, 1982).

MANAGEMENT IMPLICATIONS OF RECENT MOOSE POPULATION DYNAMICS

Moose populations on the Kenai Peninsula have fluctuated widely during the past 100 years, primarily in response to habitat changes produced by human-caused wildfires. The extirpation of wolves in the early 20th century (Peterson *et al.* 1984) and a predominantly-mild winter weather regime on the Kenai Peninsula in which occasional severe winters occur also contributed to the sharp increase in the GMS 15A moose population. These high density moose populations resulted from favorable habitat conditions created by two large human-caused wildfires on the Kenai Lowlands in 1947 and 1969.

Moose population estimates for the northern and central portions of the KNWR from 1964 to 1971 were the highest on record (since 1964 when systematic surveys were initiated) (Table 8). Estimates of moose numbers in GMS 15A and GMS 15B ranged from 3,800 to 5,300 and from 2,300 to 3,300 during this period, respectively. Evidence suggests that a decreasing habitat base resulting from forest succession in the 1947 burn and the occurrence of severe winters were the primary factors responsible for a substantial decline in these moose populations in the early 1970s. By 1975, the estimated moose populations in GMS 15A and GMS 15B had declined to 2,200 and 1,200 animals, respectively. Moose were in poor physiological condition, pregnancy rates were low, and high overwinter mortality was documented during this period (Bishop and Rausch 1974, Franzmann *et al.* 1976, Oldemeyer *et al.* 1977, Bangs and Bailey 1980).

Table 8. Moose population estimates for GMS 15A and GMS 15B, Kenai Peninsula, Alaska, 1964-1996.

	GMS 15A		GMS 15B	
Year[1]	Estimate	80% C.I.	Estimate	80% C.I.
1964	4436	3458 - 5413	2307	1578 - 3036
1965	4412	3473 - 5351	3162	2254 - 4069
1966	3849	3253 - 4446	3314	2587 - 4041
1967	4082	3217 - 4946	2689	2003 - 3375
1971	5298	4371 - 6224	2537	1869 - 3206
1973	4516	3515 - 5518	1224	812 - 1637
1974	3197	2585 - 3810	1692	1153 - 2231
1975	2175	1615 - 2734	1182	702 - 1662
1976	2831	2277 - 3386	1018	719 - 1318
1979	2589	1959 - 3220	850	533 - 1167
1982	4352	3267 - 5437	1024	710 - 1338
1987	2702	2440 - 2963		
1990	3432	3114 - 3750	1039	715 - 1363
1995	1780	1543 - 2017		
1996			942	794 - 1091

[1] 1964-67 - late fall (November-December surveys)
1971-90 - late winter (February-March) surveys
1964-82 - quadrat survey techniques (Evans et al. 1966)
1987-96 - survey technique from Gasaway et al. 1986

Source: KNWR, ADF&G

A more recent increase in the GMS 15A moose population occurred in the early 1980s in response to favorable habitat conditions created by the 1969 wildfire on the Kenai Lowlands. The GMS 15A moose population was estimated at 4,350 animals in 1982. This population has exhibited a declining trend in recent years, probably as a result of forest succession in the 1969 burn, severe winter of 1994-95, increased roadkills (near-record high of 336 in 1995), and a record harvest of 657 bulls in 1994. The 1995 estimate for GMS 15A was 1,780 moose.

Favorable habitat conditions created by the 1969 wildfire apparently had little impact on the GMS 15B moose population. It has remained relatively stable at approximately 1,000 animals since 1973 (Table 8). The most recent estimate (1996) for this management unit was 942 moose. Habitats in GMS 15B (and in that portion of the KNWR in GMS 15C) have remained relatively unchanged since major wildfires occurred in the late 1800s and early 1900s. Subalpine and riparian habitats in these areas contain willow communities in early as well as climax successional stages. These habitats appear to be the primary factor responsible for the relatively stable numerical trends exhibited by moose populations in GMS 15B during the past 20 years. Similar trends in moose populations are expected to continue in the absence of major habitat changes (via wildfire) or a several-year period of climatic extremes. Winter weather conditions, which significantly affect overwinter calf survival and thus annual recruitment, exert a major influence on moose population dynamics in GMS 15B and GMS 15C. During 1989-90, when significant overwinter calf mortality was documented in GMS 15B, combined human-caused mortality (harvest and vehicular accidents) and natural mortality probably exceeded that year's estimated annual recruitment.

The GMS 15A moose population has historically sustained relatively high harvest, including harvests of antlerless moose (cows and calves) during the 1960s and early 1970s, while habitat conditions were good. Annual harvest of bulls averaged 354 from 1963 to 1971 and 268 from 1980 to 1986, while habitat conditions were near ideal for moose in the 1947 and 1969 burns. Antlerless harvests in GMS 15A averaged 214 moose from 1960 to 1966 and 273 moose from 1970 to 1972. Recent harvests in GMS 15A and across the Kenai Peninsula declined from these levels upon implementation of selective harvest regulations in 1987. Bull harvest averaged 133 in GMS 15A from 1987 to 1990. These regulations have resulted in very conservative annual harvest rates ranging from 2.7-6.3 percent of the total population during these years.

Skewed sex ratios favoring females and male age structures favoring younger bulls resulted from past "any bull" harvest regimes on the KNWR. Lower bull:cow ratios and more unbalanced age structures occurred in more accessible areas such as GMS 15A and GMS 15B-West where harvest intensity was greatest (Table 9). Bull:cow ratios of less than 10 bulls:100 cows were recorded in some areas on the Kenai Lowlands in GMS 15A during the 1980s. Although low bull:cow ratios have not reduced pregnancy rates of moose in other parts of Alaska, potential effects of skewed sex and age structures include reduced reproductive success, a protracted breeding period which results in less viable late-born calves, and a decrease in population quality through an increase in breeding by genetically-inferior animals (Ballard *et al.* 1991).

Subalpine habitats in the Tustumena Benchlands in GMS 15B-East and the Caribou Hills in GMS 15C have historically supported the highest bull:cow ratios on the Kenai Peninsula (Table 9). Ratios ranged from 46-175 bulls:100 cows during the late 1950s and early 1960s. Relatively high proportions of bulls in these areas are older, large-antlered bulls, and these areas are important moose rutting areas (Bailey 1978, D. Holdermann, ADF&G, pers. comm.). That portion of the Caribou Hills on the KNWR may become increasingly important to moose as development occurs and access improves in off-KNWR portions of this critical moose habitat.

Table 9. Bull:cow ratios in GMS 15A, GMS 15B-East (Tustumena Benchlands), and GMS 15C (Caribou Hills), 1957-1995.

	Bull:Cow Ratio			
Year	GMS 15A	GMS 15B-West	GMS 15B-East	GMS 15C
1957	51:100	13:100	53:100	104:100
1958	48:100	12:100	48:100	139:100
1959	36:100	28:100	66:100	79:100
1960	42:100	19:100	46:100	80:100
1961	26:100	22:100	53:100	175:100
1962	17:100	15:100	49:100	38:100
1963	n.s.	n.s.	n.s.	n.s.
1964	12:100	20:100	51:100	n.s.
1965	13:100	4:100	n.s.	86:100
1966	17:100	9:100	n.s.	26:100
1967	12:100	n.s.	n.s.	25:100
1968	17:100	n.s.	23:100	n.s.
1969	13:100	26:100	33:100	19:100
1970	14:100	27:100	59:100	23:100
1971	21:100	n.s.	n.s.	36:100
1972	16:100	13:100	35:100	11:100
1973	9:100	n.s.	n.s.	23:100
1974	9:100	n.s.	n.s.	22:100
1975	n.s.	n.s.	n.s.	15:100
1976	11:100	n.s.	55:100	20:100
1977	11:100	19:100	44:100	19:100
1978	14:100	n.s.	65:100	40:100
1979	51:100	n.s.	33:100	n.s.
1980	31:100	n.s.	29:100	n.s.
1981	64:100	14:100	78:100	n.s.
1982	13:100	14:100	n.s.	21:100
1983	14:100	n.s.	63:100	18:100
1984	i.s.	n.s.	n.s.	n.s.
1985	12:100	n.s.	n.s.	19:100
1986	i.s.	n.s.	n.s.	n.s.
1987	16:100	n.s.	n.s.	n.s.
1988	18:100	n.s.	n.s.	14:100
1989	22:100	17:100	n.s.	26:100
1990	23:100	10:100	72:100	37:100
1991	22:100	n.s.	n.s.	61:100
1992	22:100	n.s.	50:100	52:100
1994	24:100	n.s.	57:100	30:100
1995	n.s.	n.s	n.s.	n.s.

n.s. - not surveyed
i.s. - incomplete survey

Source: KNWR, ADF&G

Current selective harvest regulations using antler classes for bull moose, implemented in 1987, have resulted in gradual increases in bull:cow ratios and in the number of prime-aged bulls in GMS 15A. In fall 1994, the bull:cow ratio in GMS 15A had increased to 24 bulls:100 cows. Prime-aged bull:cow ratios increased from 1:100 in 1987 to 6:100 in 1991. Although fall population composition data for GMS 15B and GMS 15C are limited and inconclusive, bull:cow ratios and the number of prime-aged bulls in these management units have apparently increased in recent years under these regulations.

The moose population increases which followed the 1947 and 1969 wildfires occurred under different predator-prey regimes. The moose population irruption following the 1947 wildfire occurred in a bear-moose system while the most recent irruption occurred in a multiple predator-moose system. Wolves, which had been extirpated in the early 20th century, recolonized the Kenai Peninsula during the 1960s and had occupied most suitable habitat by the late 1970s (Peterson *et al.* 1984). Moose are the principal prey of wolves on the Kenai Peninsula (Peterson *et al.* 1984) and are important prey of brown bears and black bears (black bears prey primarily on moose calves) (Franzmann *et al.* 1980, Franzmann and Schwartz 1986).

Highway accidents involving moose have recently become a major source of mortality for moose on the Kenai Peninsula (DelFrate and Spraker 1991). From 1984 to 1990, 225 moose were killed annually on Kenai Peninsula roads. Highway mortality appears selective for calves (DelFrate and Spraker 1991) and was the principal source of mortality for radio-collared prime-age female moose in one related study on the KNWR (Bangs *et al.* 1989). In 1995, a record roadkill of 336 moose occurred.

The natural process of forest succession on the Kenai Lowlands, the potential of severe winters predominating over a several-year period, the reestablishment of a multiple predator-moose system on the Kenai Peninsula, and high roadkill mortality have significant and immediate management implications for KNWR moose populations. The moose population in GMS 15A is the most likely KNWR moose population to be impacted in the near future by all of these factors.

Unless new early seral habitats, created by either planned habitat management or wildfire, replace those created by the 1947 and 1969 wildfires in GMS 15A, the moose population will naturally decline as forest succession proceeds in the 1969 burn, habitat management areas, and in the mid-successional forests of the 1947 burn. Early seral habitat in the 1947 burn and in the 1969 burn supported wintering moose densities as high as 10 moose/mi^2 (Table 10). The relationship between

Table 10. Estimated winter moose densities (moose/mi^2) in 4 habitats in GMS 15A, 1987 and 1995.

	1987		1990		1995	
Habitat	Density	80% C.I.	Density	80% C.I.	Density	80% C.I.
1969 burn	9.1	8.5-9.6	10.0	9.7-10.3	3.9	2.8-5.2
Residential area	1.7	0.8-2.5	5.6	4.2- 7.0	not available	
1947 burn	0.7	0.3-1.0	1.3	0.9- 1.7	0.3	0.3-0.5
Mature forest	0.4	0.1-0.7	0.7	0.4- 0.9	0.5	0.3-0.8

Source: KNWR, ADF&G

winter moose density and forest age in the 1947 burn from 1964-1990 (17-43 years post-fire) was highly significant (Loranger *et al.* 1991). Moose density in the burn declined at a rate of approximately 9 per cent per year during this period. Winter moose density in mid-successional forest in the 1947 burn declined to 1.3 moose/mi^2 by 1990 (Table 10). Winter moose density in late successional forest on the Kenai Lowlands is currently estimated to be less than 1 moose/mi^2.

Recent decreases in indices of moose reproductive success (calf:cow ratios and twinning rates) indicate that the decline in habitat quality due to forest succession in the 1969 burn may have already begun (Schwartz and Franzmann 1989). The impending moose population decline in GMS 15A as wintering habitat in the 1969 burn is lost could be abrupt if severe winters predominate over a several-year period.

Some loss of early seral forests and lower moose densities in the future in GMS 15A appear likely for several reasons. The length of the natural fire cycle on the Kenai Peninsula is unknown, but natural wildfires occur infrequently here compared to other areas in Alaska because lightning strikes for ignition are rare and fuel moisture conditions are seldom dry enough to carry a wildfire. Improved fire suppression capabilities have decreased the likelihood of large escaped wildfires, either natural or human-caused. Lastly, several factors (discussed in the Management Recommendations section of the Plan) have restricted recent habitat management activities on the KNWR. Nevertheless, planned habitat management using prescribed burning, if it can be successfully implemented, appears to the most likely means to ensure maintenance of early seral habitats capable of supporting near-current moose densities in GMS 15A.

Harvest intensity on the KNWR during the last 40 years has been greatest within GMS 15A. Consistently high moose densities, relatively easy access to much of the area, and ideal visibility conditions in burned areas were contributing factors. These same factors have resulted in ideal conditions for viewing and photography. High levels of public interest in and use of moose for both consumptive and nonconsumptive purposes will continue in GMS 15A while moose densities remain relatively high. A moose population decline in this popular area could result in conflicts between user groups and controversy regarding predator management.

Both moose and predator populations have and will continue to be impacted by humans on the Kenai Peninsula, and the results of moose-predator interactions in such ecosystems are difficult to predict (Van Ballenberghe 1987). Certain aspects of future moose-predator interactions are predictable, however. Should a population decline concurrent with a loss of quality habitat occur in GMS 15A, the moose population's rate of decrease might be accelerated by predation. Predator and scavenger populations will ultimately adjust densities downward to compensate for the decreased food supply. Low moose densities and reduced predator and scavenger populations would necessitate reduction in current harvest levels, decrease opportunities for nonconsumptive uses, and likely result in significant controversy over resource allocation. At low densities, the moose population might be regulated indefinitely by predation at densities below that which could be supported by available habitat, as is the case in many multiple predator-moose systems in North America (Gasaway *et al.* 1992).

Moose densities during winter in off-KNWR residential/developed areas appear related to winter severity, especially to snow depths in surrounding areas. Moose density in the Kenai-Soldotna-Sterling area in GMS 15A reached 5.6 moose/mi^2 during the severe winter of 1989-90 (Table 10), and a record 366 roadkilled moose were recorded on the Kenai Peninsula that year. Residential areas in GMS 15A may increase in importance as moose wintering habitat as habitat quality declines in the 1969 burn, currently the region's primary moose wintering area. If this occurs, highway accidents involving moose will remain a significant source of mortality for KNWR moose populations. The widening of the Sterling Highway between Soldotna and Sterling, may exacerbate the problem by increasing vehicle speeds.

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